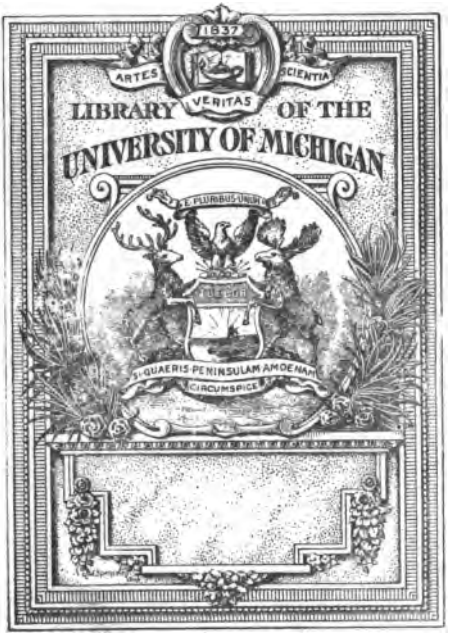
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MICROSCOPY

AND THE

Microscopical Examination of Drugs

BY

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PREFACE

The importance of the microscope and microscopical methods has greatly increased in recent years. With the large number of other branches which the student of these days is supposed to learn it becomes necessary that certain definite data be presented to him, which he may then be reasonably expected to know. Instead of relying upon the student to take notes from lectures, which as generally taken are fragmentary and often incorrect, or referring him continually to larger works on the subject, which has a tendency to confuse him it was thought best to present the essentials of microscopy in this book, based upon the work given at the college during the last four years.

This is an attempt to simplify, condense and present the fundamentals of this interesting subject. It may be used in connection with other biological work but is intended more for the use of the pharmacy and medical student. This book practically covers the work for microscopy and histological pharmacognosy as suggested by the National Committee in the Pharmaceutical Syllabus. It serves also as an introduction to the various microscopical studies and methods used by modern physicians, health officers, pure food and drug men, etc. Knowing the demands made upon the students' time, this book must necessarily be incomplete. It is hoped, however, that it will serve their present needs, stimulate their interest and arouse a desire to consult the larger works on the subject.

Use has been made principally of the following books: Organic Materia Medica and Pharmacognosy by Sayre; Botany and Pharmacognosy by Kraemer; The Microscopical Examination of Foods and Drugs by Greenish; Das Mikroskop und seine Anwendung by Hager-Mez; Mikroskopische Untersuchungen by Mez. Knowing of no book which seems to fill the place which it is hoped this will occupy, it is the author's sincere wish that it may be found to be useful and practical as a text-book and as a guide for laboratory work.

Des Moines, Iowa, November, 1911.

Chas. E. Gabel.

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PART II. THE MICROSCOPICAL EXAMINATION OF DRUGS.

INTRODUCTION

The brain receives from the outside world many sensations. The sense of sight is the most useful and instructive. Its perceptions, especially when received by an intelligent and trained mind, give us our most beautiful and valuable concepts of the objects in the universe. Primitive man was content as are the animals of today, to use the unaided eye in geting his visual impressions. Civilization and a desire to know more about the world he lived in stimulated mankind to devise means of increasing the information he might derive through his senses.

If men had studied the structure of the eye earlier than they did, they would have found in the curved surfaces of the eye, models for optical instruments. We thus see that microscopy is related to the study of anatomy and physiology, and in speaking presently of light and its relation to optical instruments we again appreciate the value of a knowledge of physics and astronomy. In the same way we shall later see that a good understanding of our subject is facilitated by a knowledge of chemistry. Likewise we shall notice that there is an inter-relation and dependence between this subject and pharmacy, medicine, etc.

Just as we consider the Swedish naturalist Linnaeus the father of botany, so we might consider the Dutch lens grinder, Leeuwenhoek, the father of Microscopy. By means of his magnifying glasses, as did Galileo by inventing the telescope, he startled the world with his wonderful discoveries. In 1673 he discovered red globules in blood. Various forms of simple microscopes, were produced by opticians and scientists in England, France, Germany and Italy. As only one kind of glass was used in these microscopes, spherical and chromatic aberration hindered the clear view of microscopic objects.

By using a diaphragm and also crown and flint glass which have different indices of refraction, these defects were remedied about 1815, by Wallaston and Fraunhofer. Having made the greatest possible correction for spherical and chromatic aberration so that the simple microscope gave the highest magnification obtainable, it was thought that no further enlargement of microscopic objects could be made. Likewise later after the compound microscope had been discovered and perfected, scientists thought that they had reached the climax in microscopy. Yet at the present time, by the aid of the ultra-microscope and photo-micrography with ultra-violet light we can get still greater enlarged views of invisible objects. What wonders of the microscopic field may not meet the gaze of the future scientist? By careful study and perseverence he gradually learns the mysteries of the minute world as the astronomer has gradually acquired more and more knowledge of the worlds surrounding the earth.

CHAPTER I.

Light.—Various Means of Enlarging Objects: Lenses, Dissecting Microscopes, Compound Microscopes, Ultramicroscopes, Microscopic Photography, Lantern Slides, Etc.

LIGHT is the phenomenon of the vibration of the ether which produces the sensation of sight. A luminous body gives forth radiant energy. If we go into a dark room we cannot recognize the objects there until a light makes them visible to us. The possibility of recognizing objects by the sense of sight depends therefore upon a source of illumination and an emanation from this capable of stimulating our retinas and thus producing the sensation of sight. If we place a window pane in front of our eyes, we can still recognize the objects in the room; we say the glass is a TRANSPARENT substance. If instead we place a piece of ground glass before our eyes we can still perceive light coming through it, but we can no longer recognize objects on the other side; ground glass is one of those substances we call TRANSLUCENT objects. If we replace it by a board, we can neither see the objects on the other side of it nor even perceive any light coming through it. We call such substances OPAQUE. When you interpose an opaque object between a light and the wall of a dark room, you observe a shadow of the object on the wall and notice an important property of light: it travels in straight lines. It was on this account that people for a long time believed in the emissive or corpuscular theory of light, which was warmly supported by Newton. According to this, scientists imagined that little corpuscles or particles were continually shot out into space in straight lines at enormous velocity. When these hit the retina of the eye they produced the sensation of sight. In the middle of the seventeenth century there was another theory to account for the phenomena of light, propounded by Huygens and called

the wave theory. When you throw a stone into a pond, the quiet water is disturbed and a series of waves start out from the center of disturbance and travel outwardly, while the water particles oscillate about a fixed point. From a self luminous body as the sun, waves of light travel similarly, except that instead of communicating their energy to particles of water, the medium along which they travel is the interstellar substance called ether, which has an enormously high elasticity and an immeasureably small density; instead of traveling in the form of a circle they travel with very great velocity (first determined by the astronomer Roemer) in the form of a sphere and instead of being visible, the individual waves are of microscopic size and invisible as sound waves. Young showed that certain phenomena could not be explained by the emissive theory but easily by the wave theory and since then the latter is practically the only one which has been considered.

RADIANT ENERGY produces thermal, luminous or actinic effects depending upon the wave length. With sunlight 200-400 millionths of a millimeter produces a strong photographic effect, 400-600 millionths of a millimeter produces the greatest lighting effect and 600-800 millionths of a millimeter wave length produces the greatest heating effect. LIGHT is thus a form of radiant energy, transmitted from place to place by means of transverse vibrations of the medium ether, which fills the whole of space.

A RAY of light (See Fig. 1) is a line of light or the straight line perpendicular to the wave front in the propagation of a light wave. A PENCIL of light is a collection of diverging or converging rays. A beam of sunlight is made up of an indefinite number of rays whose wave lengths vary from that of red to that of violet. If all rays had the same wave length it would be MONOCHROMATIC light.

When light travels from one medium to another in any way different it is in general divided into two parts, one turning back into the medium in which it has been traveling and the other travels in the second medium or else is absorbed by that medium. In the first case we say that the light was REFLECT-

ED, in the second REFRACTED. The direction of the reflected rays depends upon the angle at which the light meets the reflecting surface, and also upon the state of polish of this surface. If this polish be perfect the reflected rays will travel in such a way that the ANGLE OF REFLECTION equals the ANGLE OF INCIDENCE. The ray departing from the luminous source and striking the mirror is called the INCIDENT ray and with the normal or perpendicular erected at that point, determines the angle of incidence. With a given incident ray the REFLECTED ray moves through twice the angle through which the mirror is turned.

When a ray of light AB (See Fig. 4.) strikes a transparent medium of greater density than that in which it has been traveling, it is turned or refracted from its course, the amount of this bending depending upon the difference of density of the two media. The refraction or bending of the ray of light is FROM the perpendicular when it passes from a denser to a rarer medium. The angle which the refracted ray makes with the normal, namely the ANGLE DBN' is called the ANGLE OF REFRACTION. Experiment shows that the velocity of light in water is only about three-fourths as great as in the air. The INDEX OF REFRACTION of a medium is the ratio of the velocity of light in air to the velocity of light in that medium. This LAW OF REFRACTION of a medium is also expressed by saying that the index of refraction is the ratio of the sine of the angle of incidence to the sine of the angle of refraction. The ratio of refraction does not vary no matter what the angle of incidence is. The velocity of light in a denser medium is slower than in the air and therefore the index of refraction is greater than unity. Examples of refraction are: the seemingly broken oar in water; the fact that when a coin is put into a sink so that it can just be seen over the edge, it appears raised when water is added. An angle of refraction of about 48.5° is the critical angle for water.

A LENS (See Fig. 3.) is a circular section of any transparent substance having its surfaces either both spherical, or one of them plane and the other spherical. A ray of light pass-

ing through the OPTICAL CENTER of a lens goes through it in a straight line. Any other ray passing through the lens is refracted and the farther it is from the optical center the greater the refraction. The effect of a biconvex or double convex lens is to magnify an object, that of a biconcave lens is to diminish its apparent size.

A DISSECTING MICROSCOPE consists of a framework with a plate glass stage through which a mirror reflects the light from below into the convex lens. It is used where only low magnifications, about 4-40 diameters are required. A MAGNIFYING GLASS is sometimes known as a SIMPLE MICROSCOPE. A COMPOUND MICROSCOPE consists essentially of a similar lens to which the eye is applied and known as an OCULAR and another lens or system of lenses near the object to be looked at, known as the OBJECTIVE. These are usually connected by a tube which is vertically attached by means of a RACK and PINION to a PILLAR held upright by a BASE. A projecting platform which carries the object to be examined is called the STAGE. Below this a MIRROR reflects light upwards. This is sometimes concentrated on the object by means of the ABBE CONDENSER, a short cylinder attached below the stage, consisting essentially of convex lenses. It may also contain a DIAPHRAGM and a BLUE GLASS. A minerological microscope is merely a modification of the ordinary compound microscope, an opening is in the side of the tube into which various plates may be put for aiding in the examination of the object. Below the stage is a polarizer with a projecting graduated collar. A similar horizontal plate marked in degrees is above the eye-piece on the analyzer. Greater contrast in polarization may be obtained by placing a selenite or mica plate above the polarizer.

CHAPTER II.

Accessory Parts. Manipulations and Care of Microscopes.

An object, for example a hair, may be held below the objective of a microscope and examined. For the sake of convenience, however, we usually put it on a 1x3 inch glass SLIDE which may be held in its place by spring CLIPS and cover it with a circular or square piece of thin glass, the COVER SLIP. A glass slide with a concavity in its upper surface is known as a HANGING DROP SLIDE. One with a small scale marked or photographed on it is called a MICROMETER SLIDE, or STAGE MICROMETER. An object put on this can be directly measured. A circular glass disk containing a scale, to be placed upon the diaphragm of an eye piece for measuring objects under the microscope, is known as an OCULAR MICROMETER. There are various devices to facilitate the mechanical reproduction of objects as seen under the microscope. However, for the beginner free hand drawing is most desirable and an accomplishment which it will be necessary for him to acquire. A MECHANICAL STAGE is an attachment which is sometimes fastened above the stage of a microscope to carry the slide and enable one to examine it more thoroughly and relocate a structure more readily at any subsequent time. Besides the two-thirds and one-sixth inch objectives ordinarily used and attached to a REVOLVING NOSEPIECE, the one-twelfth OIL IMMERSION OBJECTIVE (See Fig. 14.) is used when a higher magnification is desired. In this case cedar oil is usually put on the covered object to be examined and the objective is lowered into it. Having about the same refractive index as glass it prevents a scattering of the light coming from the object. The higher an objective magnifies the smaller is its APERTURE (See Fig. 5.). The working aperture of the lens can be made still smaller by using one of the various kinds of

diaphragms which may be attached below the stage of the microscope. The IRIS DIAPHRAGM usually used is a part of the ABBE CONDENSER which consists essentially of one or more convex lenses for the purpose of concentrating the light on the object to be examined. On its lower side it may also carry a ring into which a blue glass disk may be placed whose purpose is to counteract the yellowishness of the microscopic field caused by the use of artificial light. This ABBE CONDENSER may be removed and into the collar which held it in place may be put a POLARIZER. (See Fig. 15.). The principal part of this is the Nichol Prism which is made by cementing together with Canada Balsam, two suitable pieces of Iceland Spar. Usually, besides the polarizer we also use an ANALYSER which is similarly constructed, but placed directly above either the objective or ocular. By turning the polarizer, the field becomes dark and the phenomena of POLARIZATION are seen. This is needed for the investigation and identification of many objects in the plant and animal world but especially for minerals.

To use the microscope turn the plane mirror so that it reflects light into the objective, which can be seen by placing the eye to the ocular. Then put the object to be examined directly below the objective. The space between the object and the objective when the microscope is properly focused is called the working distance. The focal length of the objective is considerably less than this. Thus when using a two-thirds or 16mm. objective the front lens of the objective must be less than two-thirds inches from the object in order to bring the latter into focus. When focusing always use the low power, that is, the objective with the large front lens, first. With the eye on a level with the cover glass use the coarse adjustment to lower the objective to less than the working distance from the object. Then place the eye to the eyepiece and gradually raise the tube until the object comes into view. Then by using the micrometer screw you can focus more accurately and conveniently and get to different OPTICAL PLANES in the object. Before using a higher power move the slide so that the point you wish to magnify is in the center of the field, as the higher

the magnification the smaller is the field covered by the microscope. Then raise the objective so that in revolving a higher power into place the lens will not strike the cover glass. With artificial light use the CONCAVE MIRROR. When the object is too brightly illuminated turn the mirror slightly or cut off some of the light by using the diaphragm.

When through using a microscope return it to its case by first lowering the objective, pushing the mirror-bar to one side and carrying the instrument by the pillar below the stage. Taking hold above the stage may injure the delicate mechanism of the fine adjustment. Before using the microscope unscrew the objectives and examine the front lens. Also see if the eyepiece is clean. If not, wipe with a clean, soft linen or silk cloth. If this does not make it clear apply a drop of chloroform or tell the instructor about it. Do not touch the lenses with your fingers or rub them with a coarse or dirty cloth. Never use a one-sixth or higher power unless you have a cover glass on the object, otherwise, you will not see the object well and may scratch the lens or get something on it. The large milled head attached to the pinion is used in the COARSE ADJUSTMENT, a smaller head or screw is used in the FINE ADJUSTMENT of the tube to the object.

The facts revealed to us by the microscope have been numerous and wonderful and various sciences have greatly profited by its use. Yet higher magnifications would be very desirable as some biologists think there are organisms so small that they have not yet been made visible and chemists wish to know what molecules and atoms look like.

When sunlight enters a small hole in a darkened room the particles of dust in it which could not be seen before are made visible. Similarly dark ground illumination was improved in 1903, by illuminating the field by a cone or wedge of light from the side. ULTRAMICROSCOPY thus enables us to see on a dark field minute particles which otherwise were invisible. Objects so extremely small as five millionths of a millimeter have thus been seen.

Just as we can get a picture of a landscape, so by suitably adjusting a camera to a microscope we can photograph the

field of vision. For PHOTO-MICROGRAPHY, however, it is desirable to have a camera, tube and objective especially adapted for the purpose. The camera is placed either below the microscope or attached above it to a supporting column on which it may be moved vertically. A dark cloth covers the connection between the lens of the camera and the ocular to keep light from entering at that place. Either daylight or artificial light passing through a condensing lens may be used to make the NEGATIVE. From this negative PRINTS (MICRO-PHOTOGRAPHS) may be obtained as ordinarily made by a photographer. If instead of using printing paper we substitute a photographic plate and expose to the light, a POSITIVE is obtained in which the light parts of the negative are dark and the dark parts of the negative are light, thus giving the distribution of light and shade as in the original view. From this positive a LANTERN SLIDE can then be made by protecting the film side with another plate of glass and binding the two together at the edges. By means of a PROJECTION LANTERN an enlarged view of the slide can then be thrown upon a white screen and be seen by a large audience. Instead of making lantern slides, microscopic objects may be directly projected upon a screen by properly attaching a suitable microscope in front of the lantern.

Recently a method has been devised in which it is claimed by the use of ULTRAVIOLET- instead of sun-light, prints could be made in which objects appeared again as large as in the ordinary micro-photograph. Ultraviolet light is of shorter wave length than violet light and therefore not visible. Although our retinas are not sensitive enough to preceive it, it does however affect the photographic plate. As it is monochromatic the microscope need not be corrected for chromatic aberration. As glass is not transparent for these rays but quartz is, the latter material is used for the condensers, objectives, oculars, slides and cover glasses.

A person can get accustomed to working with a microscope so that it will not be more fatiguing than looking at other objects. Divide the work between the right and left eye and keep the unused eye open. An eye-shade is useful for

those who have trouble in keeping both eyes open while looking through the microscope. It may be made from a rectangular piece of cardboard or wood blackened above and provided with a circular opening at one end which fits over the upper end of the tube. Avoid an illumination which is too strong or too dim.

CHAPTER III.

The Reproduction and Measurements of Objects Under the Microscope.

In drawing a microscopic object, the rules and directions for ordinary drawing apply also. Use low powers first to outline the object. Then after having carefully examined the object under a higher power, put in details. If necessary draw an enlarged view of part of an object. (See Fig. 36.) Avoid the general tendency of making such drawings too small. The entire depth of the object may not be visible, therefore, focus carefully so that by seeing it at different focal planes it can be more readily understood. When the drawing has been satisfactorily outlined with light lines, retrace with heavier lines, label the parts and give the drawing a neat finished appearance. For making enlarged reproductions of microscopic structures quickly and accurately, a CAMERA LUCIDA may be used. In the form devised by Abbe (see Fig. 16) the eye sees at the same time the object and the drawing paper at its side. The light coming from the paper is reflected by a mirror attached to the microscope, passes into a prism which is fastened above the eyepiece and is reflected from that into the eye. In the Leitz drawing ocular a prism is attached to one side of the ocular so that rays of light coming from the drawing are twice totally reflected in it and enter the eye with the ray of light from the object. In another form of camera lucida (Beale's) the tube of the microscope is placed horizontally and a smoked glass is attached obliquely near the eye lens. When using a drawing apparatus the details of structure are not seen plainly, but the outlines of an object can be more accurately obtained than is otherwise the case. It is also the most suitable means for measuring the size of an object. After

an object has been drawn, substitute for it a stage micrometer and the dimensions can there be directly indicated on it. Or, in place of the drawing, substitute a rule and thus determine how much larger the drawing is than the object. Thus if 1 mm. on the stage micrometer covers 50 mm. on the drawing, the object will appear enlarged there 50 times. The unit for microscopic measurement is the MICROMILLIMETER or MICRON, 1 μ equals .001 mm. On the scale of the ocular micrometer each mm. is usually divided into 10 or 20 parts. This micrometer is placed on the diaphragm of the ocular (see Fig. 17.) where a real image of the object comes to a focus. Both the image and scale are then magnified by the eye lens. This branch of science is known as MICROMETRY. By applying its methods we can thus distinguish e. g. rice starch grains from oats starch grains which otherwise are very similar.

CHAPTER IV.

Histology.—Microchemistry.

In examining an organism we find it is built up of various tissues. There are usually strengthening, storage, protective, secretive, nutritive, reproductive, etc., tissues. As the name implies (histos=tissues and logos=science), HISTOLOGY tells us about the tissues. Another name for this science is microscopic anatomy. It also informs us of the cells of which tissues are composed, with what they are held together and the various things cells contain. Histology thus tells of the minute structure of a plant or animal. Not only does it inform us about the form, shape, appearance, etc., of the units of structures, the cells, but it also deals with the methods of preserving and preparing them for microscopical examination. A knowledge of the details of this subject and the ability to recognize and understand the things he sees under the microscope are of great value to the pharmacy and medical student. Life processes are connected with a jelly-like substance called PROTOPLASM. This is usually partitioned off into compartments called CELLS. Within these, various interesting physical and chemical changes take place. The cells are manufactories of a great variety of important substances. Some of their products, as coloring substance, protective substance, flavors, oils, or those used for food or to cure diseases, cannot be made by a chemist, others have been manufactured by him. By learning more about the structure and activities of protoplasm, the material in which life processes occur, he may be able to imitate nature still more successfully.

Some chemical processes, on account of the dilution of the reagents used or the small quantity of the active substance present, give reactions which are not visible to the unaided

eye. MICRO-CHEMISTRY concerns itself with those chemical reactions which are observed by using microscopical methods. For example grape sugar may be demonstrated by Fehling's solution, or starch by Iodine solution, in sections where they would otherwise escape detection. The various processes of staining tissues, so that in the microscopical preparations the various parts are better differentiated, visible and beautiful, are largely due to chemical reactions, some of which are yet imperfectly understood. For micro-chemical analyses petrological and chemical microscopes are very useful. To protect an objective against injurious gases attach a cover-glass to it with some transparent substance like Canada Balsam.

CHAPTER V.

The Preparation of Objects and Mounting for Microscopical Examination.

Although some objects may be observed directly under the microscope, most of them must be suitably prepared. Small opaque objects may be seen by reflected light. In general we examine by transmitted light, that is, the light passes from below through the object which is or has been rendered more or less transparent. Some herb stems for example have such a consistency that they may be easily cut with a sharp razor, into thin slices for microscopical examination. Others which are too soft may be hardened by soaking in alcohol, those which are too hard, as many medicinal plants which the druggist receives must be softened by lying in water. Some may even require boiling. Those which are very resinous should first be soaked in alcohol. For greater convenience of cutting sections some tissues are embedded in pith, cork, paraffin or collodion. Blocks of these may then be attached to instruments known as microtomes which cut sections more evenly and quicker than can be done by the free hand method. A suitable thin section may still be opaque until it is rendered transparent and a very transparent substance may be more easily examined after it has been stained.

Sections may be mounted: 1, in fluids; 2, in solid media; 3, dry. Under the first division we usually use water, glycerine, or alcohol or a mixture of these in various proportions depending upon the purpose for which it is used. Alkalies or acids are sometimes used to help disintegrate the tissue or produce some change in it. Solid media are made liquid before objects are mounted in them. Thus xylol or chloroform is added to Canada Balsam to dissolve it or make it flow more

readily, and glycerine jelly is heated before being used. A dry mount may be made by painting a circle with Canada Balsam or some other suitable substance on a glass slide. Or a ring may be fastened to it. Sometimes a white or black disc is first fastened below this in the center of the slide. On it and inside of the ring is then placed the object (seeds and fruits like anise). A cover is then cemented on. A leaf preparation may be similarly made by cutting out a disc and fastening it with shellac varnish.

CHAPTER VI.

Cells and Their Contents.—Tissues.—Organs.

The unit of structure of organisms is the CELL. A knowledge of the construction and activities of the cell is of the utmost importance as it helps to explain the life processes of the organism. PROTOPLASM, the living material in the cell is the substratum or the physical basis of life. Cells may have various forms e. g. spherical, oval, cylindrical, polygonal, or they may have the shape of a boat, disc, triangle, crescent, club, spindle and mosaic.

The jelly-like protoplasm of the cell is usually held within a retaining membrane, the CELL WALL which is especially well developed in plant cells, while we more frequently find naked cells in the animal kingdom. Another specialized part is the usually roundish NUCLEUS, a denser substance than the protoplasm surrounding it, and usually at its center or most active part. A nuclear membrane surrounds the nucleoplasm. In the latter is usually found a nucleolus, or there may be two or more nucleoli. Probably the most important part of the cell, as it is supposed to be the bearer of the hereditary qualities, is the CHROMATIN SUBSTANCE, so called because it can readily be stained. It is in form of a granular net work, ribbons or bars, well protected within the nucleus. In the protoplasm also are found granules which, however, do not appear to be important, and vacuoles filled with cell sap which cause turgidity of the cell by distending its cell wall.

The cell wall is made of cellulose, or in a few cases of silica. In many plant cells the walls are lignified or woody, while in the barks they are suberized or corky. A substance very frequently seen in great amounts in cells is the carbohy-

drate STARCH, which is formed by the PLASTIDS into grains of various shapes and sizes. A related substance, INULIN is sometimes formed. It is found in the following drugs: Inula, lappa, pyrethrum, and taraxacum. SUGARS, PROTEID MATTER AND ALEURONE GRAINS are also produced by cells. MUCILAGE is sometimes formed, as well as RESIN and TANNIN. FAT and FIXED or VOLATILE OILS are frequently present. The ALKALOIDS or vegetables bases (e. g. coniine, piperine) formed by the cells usually give the plant its medicinal value as in Cinchona, hydratis, nux vomica and poppy. CRYSTALS of calcium carbonate, calcium tartrate and calcium sulphate are sometimes present though usually the crystals are composed of calcium oxalate. The latter are insoluble in acetic acid but soluble in HCL. HCL and also acetic acid dissolves calcium carbonate with effervescence.

Crystals are formed by a definite arrangement of the molecules of matter. They are regular geometric solids resulting from the action of natural forces with smooth faces meeting in straight edges and forming perfect angles. There are many forms of crystals but usually each kind of substance crystallizes in but a single form which thus furnishes a means of identifying the substance. Thus, knowing that KI crystalizes in cubes and no other form, we know also, that any substance exhibiting some other form of crystallization is not KI. Substances capable of crystallizing in two different forms are said to be dimorphous, e. g., S and $CaCO_3$. There are also some trimorphous and polymorphous substances. Similarity of their composition is apt to be attended by similarity of crystal form. Two or more crystal individuals of the same kind when grown together are known as twin crystals.

Crystals form when a molten mass solidifies, when a solution is evaporated until supersaturated or more rarely from vapors. The angles of crystals are characteristic for the substance so that substances may be identified by measuring their angles with a goniometer. External causes may modify the completed shape of crystals. The many different forms in crystals may all be referred to six plans called systems. These depend upon the arrangement of the faces and angles about the

axes which are imaginary lines in the crystal. Thus in the Isometric crystals there are three equal axes at right angles to one another, in the Monoclinic crystals two of the axes are at right angles and the third is inclined, in the Triclinic crystals there are but three equal axes but all inclined to one another, in the Hexagonal crystals the three equal axes in the same plane intersecting at angles of 60 degrees are at right angles to a fourth axis.

The science which treats of crystals is called crystallography. Crystal structure was thought to be due to the grouping of the molecules in it. Having studied the properties of crystals, crystallographers determined by mathematical calculations that there ought to be thirty-two different classes or arrangements possible. Of these theoretical forms twenty-three were found in crystals known at that time, six were discovered in the next eight years and none were ever found not in accord with the classification.

Crystals of the monoclinic system are widely distributed and include the following forms: prisms, pyramids, polygonal-shaped and rosette shaped crystals, raphides, crystal fibres and crytocrystalline crystals. The crystalline form is less frequent than amorphism among the natural products derived from the animal and vegetable kingdoms. Amorphous substances are those without any indication of crystalline structure, e. g. cellulose and albumen. Some substances which to the unaided eye appear without crystalline form, consist in reality of minute crystals visible under the microscope and, therefore, called micro-crystalline. Crystals grow from without by the deposition of similar material; cells grow from within by the assimilation or intussusception of material which is different from protoplasm.

Crystalloids are angular in form, but their faces and angles are inconstant. They are insoluble in water, but absorb it and swell which does not occur with ordinary mineral crystals. Crystalloids are small granules of proteid material called globulin. They may occur alone or in the cytoplasm or when one is combined with a globoid it forms an aleurone grain.

Colloids, e. g. dextrin, gum, gelatin, agar, etc., when dis-

solved, diffuse very slowly and have scarcely any effect on the freezing point of the solvent. The colloids do not dialyze, i. e. pass readily through membranes. This is due probably to their large molecules.

A group of similar cells doing the same kind of work is called a tissue; such are: epidermal or surface limiting membranes, supporting tissues such as wood and bast fibres in plants, and osseous and connective tissues in animals, conducting tissues, etc.

An organ is a group of tissues and has a certain function to perform in the organism. Thus leaves and lungs are respiratory organs while roots and intestines are organs for absorbing food material.

CHAPTER VII.

Plant Hair. Root. Stem. Leaf. Flower. Fruit. Seed.

The vegetative organs of a plant are hair, root, stem, and leaf, the reproductive organs are flower, fruit and seed. Plant hairs are out-growths of epidermal cells and may be unicellular or multicellular, branched or unbranched, glandular or non-glandular. The glandular hair have a knob-like extremity and secrete some substance. In powders, sclerenchyma fibres might be mistaken for hair, however, the former are colored red by applying phloroglucin-hydrochloric acid, while the latter are not.

Roots conduct the water and mineral matter which it holds in solution and which was taken up by the root hairs to the stem and leaves. This sap is conveyed along tracheal tubes in the central part of the root. Other vessels, the sieve tubes, carry elaborated food back to the roots. These are not stained red by phloroglucin-hydrochloric acid while the tracheal tubes are. The latter are arranged radially, with many rays in monocotyledonous plants and few in dicotyledons. Besides these, spindle shaped, thick walled sclerenchyma fibres give support and strength to the root enabling it to hold the plant in the ground. These structures are surrounded by a layer of endodermal cells, and then by many layers of thin-walled cortical parenchyma cells.

Rhizomes or underground stems do not have the radical arrangement of the tracheal tubes. However, old and woody roots may lose this characteristic, yet can be distinguished as roots by the fact that as seen in a longitudinal section the tubes of a branch arise from the central part and not from the outer parts as they do in stems. Underground stems, as root-stocks and tubers, are characterized by the large number of

parenchyma cells they contain filled with reserve food material and by containing little lignified tissues.

Overground stems have differentiated their cells so that they are better adapted to serve the functions of the organ: to conduct fluids, and give strength and elasticity to the part. Young green stems also function as respiratory organs for which purpose they possess breathing pores, the lenticels. Stems form a large number of elongated thick walled woody cells, between which are the tracheal cells which have developed into conducting tubes. These surrounded by the woody fibres constitute the fibro-vascular bundles. The distribution of the latter determine the type of stem. (See Fig. 33). The fern type is characterized by having its several fibro-vascular bundles arranged in the spongy parenchyma in the form of a circle; the monocotyledonous type has a large number which are scattered irregularly; the dicotyledonous type has still larger numbers which are arranged into groups by the medullary rays and annular rings.

A leaf usually has an upper protecting layer of flattened cells, the epidermis. This rests upon a row of palisade (columnar) cells. Beneath this the branching or irregularly shaped spongy parenchyma cells are loosely arranged for respiratory purposes. These and especially the palisade cells contain the photosynthetically active chloroplasts. The lower epidermis protects the under side of the leaf. Usually it and not the upper epidermis has the stomata. The epidermal cells of both may bear hairs. At the midrib and veinlets we may also see conducting tubes and woody cells. (See Fig. 53.)

Flowers as modified branches whose purpose is not to nourish the plant but assist in the perpetuation of the species, have their leaves accordingly modified into sepals, petals, stamens and pistils. The petals are usually brightly colored by chromoplasts, compressed dorsoventrally, both sides being more nearly alike and usually possessing papillae. These give the petals a velvety surface.

Fruits show much diversity of microscopical structure. Usually there is an outer epidermis separated from an inner epidermis by parenchyma. The latter may be traversed by

fibro-vascular bundles, milk vessels and oil canals while its cells may contain starch, sugar, oil, crystals, alkaloids, protoplasm, pigments, etc., or contain groups of stone, sclerenchyma or collenchyma cells. The inner and outer epidermis may contain various outgrowths and stomata.

The microscopist is frequently called upon to investigate powdered seeds of various plants. As these reproductive bodies are richly supplied with reserve food material, their identity is easily determined. The embryo contains parenchyma cells and a few fibro-vascular bundles. It is usually surrounded by the endosperm and perisperm which consists of parenchyma cells. These may contain starch, proteids, oil and alkaloids. All this is enclosed by the seed coat, and may be further protected externally by the pericarp whose cells form the bran obtained from cereals. The seed may be smooth externally or hairy, winged, reticulate, pitted, or possess a caruncle, arillode, etc.

CHAPTER VIII.

The Microscopy of Starches.

Starch is a very important and widely distributed organic substance produced from inorganic raw-materials by the chloroplasts in the cells of leaves. By the action of ferments this Assimilation Starch is changed to a soluble carbohydrate conveyed to other parts needing nourishment or deposited as Reserve Starch chiefly in seeds, or underground organs. The grains deposited in stems are smaller and more spherical. The kind of starch grain formed is characteristic for the kind of plant producing it. A careful study of the starches is, therefore, of the utmost importance in detecting adulterations, in identifying the commercial varieties of starch and in distinguishing starch containing drugs from one another. Particles under the microscope may be identified as starch by their reaction to polarized light and to iodine solution. The latter stains them bluish to black, while the former produces two dark bands on the grain which cross at the hilum, i. e. the point of origin of growth. To distinguish starches of different plants from one another we note whether the hilum is central or excentral, wanting, indistinct or prominent, cross-shaped, three or five-angled, round or fissured. How the lamellae or striations run, their distinctness or absence, the shape and size of the grain are also important. Starch grains kept at least fifteen minutes at 50 degrees C. show their structure better. The effect of polarization is increased when the grains are mounted in a fixed oil. The grains often look like clam shells and are 1 to 100 microns in diameter. They should be examined in water. By putting alcohol to the cover glass the grains are caused to roll and may be seen on side view. Moist heat and alkalies cause the grains to swell and gelatinize, while they can be dissolved by strong HCL and H_2SO_4.

CHAPTER IX.

The Development of Plant and Animal Tissues.

If the unicellular reproductive bodies of bacteria, yeast or mold be suitably mounted in hanging drop preparations, we may follow their growth under the microscope. The spore absorbs moisture, enlarges, ruptures its walls and the new organism begins its development. Similarly other thallophytes, bryophytes and pteridophytes begin their life history. When the multicellular embryo of spermatophytes which formed from the unicellular egg-cell after fertilization in the flower, resumes growth during the sprouting of the seed, it corrodes the starch stored up in the endosperm and with the food thus obtained its caulicle is lengthened into the radicle and this later forms the roots. Likewise the plumule enlarges into the stem, branches and leaves of the seedling. In young cells no vacuoles may be visible. As the cell matures, clear-colored spaces filled by cell sap appear and keep up the turgescence of the cell, thus increasing the size of the cell wall and that of the cell without using up a corresponding increased amount of the valuable cytoplasm. In still older cells the nucleus has assumed a still more parietal position. Although it has been increasing in absolute size, it is relatively smaller than in the young cell. The cytoplasm surrounding it is connected by strands with that lining the cell wall. The granules in this may sometimes be seen in motion, or a whole strand may shift its position between the vacuoles. By dividing the apparent rate of motion of an object under the microscope by the magnification we get the actual rate, which thus seems quite slow. Physical and chemical changes probably cause and modify many of these movements. A rotatory movement may be observed in leaf cells of Elodia, a circulatory movement in the staminal hairs of Tradescentia and a translocation movement

in the creeping plasmodium of Myxomycetes. Besides this intracellular movement the cell as a whole may move from place to place as the result of some intracellular power. Thus diatom, ciliated and ameboid motions may be called locomotive. The purpose of some of these is by bringing the reproductive bodies together or by enabling them to scatter over wider territory, to increase the number or vitality of the species, and thus favor its further development. The cells of some of the lower organisms reproduce by the nucleus first simply separating into two parts which then pass into the two halves into which the cell is constricted and later separated. A more complicated method than this DIRECT CELL DIVISION is the INDIRECT METHOD OF CELL DIVISION, MITOSIS, or KARYOKINESIS, seen in higher forms. Here the resting nucleus shows the net work of chromatin substance. This then changes into a shorter, thicker, coiled thread. This divides into segments each of which is longitudinally divided. These chromosomes, the number of which is constant for each species, become V-shaped and arranged in the equatorial plane with their apices toward the center. Next they separate longitudinally each half seeming to be drawn by the threads of the kinoplasmic spindle toward the polar bodies. There they unite to form the nuclear thread of the daughter nucleus. This then changes to the nuclear net, while the polar body forms the centrosome of the new cell. Nuclear membrane and partition wall also form. (See Fig. 32.) In REPRODUCTION BY BUDDING, (see Fig. 35, z), the mother cell forms an outgrowth which increases in size and becomes separated from the parent by a wall. In FREE CELL FORMATION, the nucleus divides repeatedly and each part becoming associted with some cytoplasm, a number of daughter cells are produced.

The embryonic cell is soft, isodiametric, thin-walled and multiplies rapidly. It may develop differentiated cells which are elongated, hard, have walls that are thickened, regularly or irregularly, fissured or perforated, suberized, lignified, or the protoplasm may contain stored up starch, alkaloids, crystals, etc., or form plastids, or having fulfilled its functions may disappear or be used by neighboring cells.

In certain parts of the plant as the apex of root and stem, cambium and cork cambium, the cells retain the power of active multiplication by division. These are known as meristematic tissues. These apical cells of the root and stem from which the other cells and tissues must be differentiated are known as the PRIMORDIAL MERISTEM. This forms three different tissues known together as the PRIMARY MERISTEM: 1, the protoderm, whose cells are somewhat elongated and which later form the epidermis; 2, the procambium, a hollow tube-like structure of cylindrical cells which by their great powers of division and differentiation produce on both sides fibres and vascular tissues, while the cambium tissue of the mature plant remains active between them; 3, the ground or fundamental meristem is the tissue inside the procambium. The tissues arising from the primary meristem are known as the PERMANENT TISSUES. These in adaption to the functions they perform acquire a modified and fixed character and lose the power of dividing, although this may be revived under unusual circumstances. This power of dividing, however, is retained as the peculiar function of the cambium cells which thus constitute the SECONDARY MERISTEM. These relations may be represented as follows:

	PRIMARY MERISTEM	PERMANENT TISSUES	Secondary Meristem
Apex — Primordial Meristem	Protoderm	Epidermis	
		Cork	
		Cork Cambium	Cork Cambium
	Procambium	Phloem	
		Cambium	Cambium
		Xylem	
	Ground Meristem	Pith	
	Procambium		
	Protoderm		

The epidermis which we find in pteridophytes and phanerogams completely covers the plant and protects it in various ways. The cells are firmly bound together without any intercellular spaces. An almost complete imperviousness

to water and gases results from the cuticle or the outer wall of the epidermis and the suberin of the cork cells except in those parts adapted to absorption. The usually single layer of epidermal cells may by tangential fission form a multiple epidermis. A hypoderma of thick-walled elongated cells may be formed from the fundamental tissue immediately beneath the epidermis. Besides the cuticle, a coating of wax often enables the epidermis to reduce transpiration. Respiration also occurs through the stomata whose size is regulated by the guard cells. These contain chloroplasts and starch grains which other epidermal cells do not as they consist mostly of a cell cavity with watery sap. This is surrounded by a thin layer of protoplast lining the cell wall. In coniferae and perennial dicotyledons the epidermis is replaced by cork cells. These are brick-shaped and tightly joined together. They usually contain only air and sometimes brownish tannin-like substances. One or more layers do not thus change, but the cells retaining the power of division are known as the cork cambium or phellogen. This together with the cork is called the periderm. A proliferation of cork cells which become loosened from one another and rounded forms a brownish protuberance at the surface known as a lenticel. This has the same function as the stomata of a leaf.

From the procambium many cells are split off both on the outside and inside, these elongate and are modified to better perform their functions. Those which by the lengthened cells joining end to end become tubular are known as ducts. Such are the sieve tubes in the phloem and the tracheal tubes in the xylem. Near these are the bast and woody fibres respectively which are cells that have lengthened to a spindle shape and acquired thicker and lignified cell walls. Thin-walled elongated companion cells are adjacent to the sieve tubes. The latter are expanded at intervals where the perforated sieve plates have developed. The tracheal tubes have ring-shaped, spiral, etc., thickenings of their cell walls, which keep an open passage way for the ascending sap. Although these cells have lost their protoplasm, others sometimes also formed here retain theirs, remaining thin-walled and short. These con-

stitute the wood and bast parenchyma and are separated by the stratum of actively dividing cambium cells. The primary vascular bundle is this group of tissues thus differentiated from the procambium. It is usually wedge-shaped with its apex toward the pith. This is the open, collateral bundle. The closed bundle results when the entire procambium is transformed into permanent tissues but no cambium is formed. This condition for which we may take the corn stem as an example is found in monocotyledons and some dicotyledons. The concentric bundle is formed when the phloem surrounds the xylem of the bundle. This condition we see in the stem of ferns and many water plants. In the rhizomes of some monocotyledons the xylem surrounds the phloem. The bicollateral bundle has a second phloem on the pith side. This is found in many plants e. g. in the milkweed, mint and cucumber families.

Inside of the xylem is the pith developed from the ground meristem, or fundamental tissue. Its isodiametric or slightly elongated cells have usually thin walls of cellulose. Often growing slowly they may become torn or obliterated. Their protoplasm is frequently used and replaced by air, or large intercellular spaces are formed. The fundamental tissue is used for storing up reserve food material. It composes the chief part of fleshy roots, rhizomes, corms, bulbs, tubers and fruits. The cells of the fundamental tissue may, however, also be otherwise differentiated, forming e. g. just beneath the epidermis collenchyma, stone cells, bast cells or latex cells. Latex cells may fuse and anastomose, forming the laticiferous vessels. These do not have parallel sides or run in parallel courses and convey a milky fluid, the latex, containing in solution various salts, mucilages, sugars, tannins, proteids and alkaloids and in suspension fine particles of starch, resin, gums, oil, etc.

After the plant cells have become differentiated into the permanent tissues and attained their full size the organ ceases to grow in thickness unless a secondary meristem is formed. In most dicotyledons and gymnosperms however, a region of the primary meristem remains and continues to form new cells. That part within a fibrovascular bundle is called the fascicular cambium while the part between the bundles is called the inter-

fascicular cambium. This meristematic zone may be circular or wavy in its course about the xylem. Its cells divide repeatedly by forming tangential, radial and cross walls. The secondary increase is mainly due to the increase of xylem cells formed by the cambium zone. The latter also produces externally the protein-rich cells of the phloem. Outside of that the fundamental tissue may also form a phellogen which produces new cells. In the xylem formed in the Spring, large tracheal tubes or tracheids predominate, later small and stronger tubes and fibres are formed. This process repeated every season produces the so called rings of annual growth in stems of gymnosperms and dicotyledons. Monocotyledons do not have them. (See Fig. 33.)

Roots are similarly developed but owing to the differences in their functions they show corresponding morphological variations. In a young root we find a hairy epidermis, the root hair being unicellular. Inside of this there is frequently a one to several-celled thick exodermis (hypodermis). Within this is the many-celled deep cortical parenchyma, the innermost layer of which (endodermis) surrounds the central part (central cylinder or stele). This woody part (xylem) of the root, has an outer stratum two or three cells deep known as the pericambium or pericycle, which may produce cork and a secondary cortex or it may produce new lateral outgrowth. Into these extend the hadrome or the bundles of tracheal tubes and woody cells. Alternating with the hadrome and also radially arranged is the leptome (sieve strands) or the food conducting tissue. These radii are numerous in monocotyledons e. g. sarsaparilla where a central medulla (pith) is also present. (See Fig. 37.) A cambial zone forms, curving to the inside of the leptome strands and outside of the hadrome. It forms more leptome towards the periphery of the hadrome and consequently a radial fibrovascular bundle. Thus the radial arrangement of the primary root scructure is converted into the collateral kind of secondary root scructure.

CLASSIFICATION OF PLANT TISSUES.

I.—Parenchymatous Series.

1. Parenchyma, or soft tissue.
2. Collenchyma, or thick-angled tissue.
3. Sclerotic parenchyma, or stony tissue.
4. Epidermal, or boundary tissue.
5. Endodermal tissue.
6. Suberous or corky tissue.

II.—Prosenchymatous Series.

7. Wood or libriform tissue (woody fibre).
8. Tracheids or vasiform cells.
9. Ducts or vascular tissue, including
   - a. Dotted ducts.
   - b. Scalariform ducts.
   - c. Spiral ducts.
   - d. Annular ducts.
   - e. Reticulate ducts
   - f. Trabecular ducts.
10. Hard bast tissue or liber fibre.

III.—Sieve Series.

IV.—Laticiferous or Milk Tissue.

- a. Simple.
- b. Complex.

CLASSIFICATION OF ANIMAL TISSUES.

I.—Epithelial or Surface limiting.

1. Epidermis. 2. Mucous Membranes.
3. Terminal parts of organs of special sense.
4. Inner surface of serous membranes.
5. Inner surface of heart, blood vessels and lymph vessels.
6. Inner lining of ventricles of brain and of central canal of the spinal cord.

II.—Connective or supporting.

1. Connective tissue proper:
   a. Yellow elastic. b. White fibrous.
   c. Areolar. d. Adenoid.
   e. Adipose.
2. Cartilage.
   a. Hyaline. b. Fibrous (white and yellow).
3. Bone.

III.—Muscular or contractile.

1. Voluntary.
2. Involuntary.
   a. Spindle-shaped. b. Heart.

IV.—Nervous or sensory.

1. Cerebro-spinal.
2. Sympathetic.

V.—Blood and Lymph or nutritive.

1. Plasma.
2. Corpuscles.

These various tissues of the adult are generally formed from the following three layers of the embryo: Epiblast or outer, Mesoblast or middle and Hypoblast or inner layer. These embryonic structures have formed by repeated divisions from the single ovum or egg cell. By outfoldings and infoldings of the layers of cells, organs and glands developed. Thus the very large number of cells which are generally found in the full grown animal or plant were all derived ultimately from a single cell whose further development was determined by heredity and environment.

QUESTIONS ON MICROSCOPY.

1.

1. With what other sciences is microscopy related?
2. What were the defects of early microscopes; how and by whom were they corrected?
3. Define: transparent and light.
4. Define: micron and pencil of light.
5. What can be said about the wave length in sun light.
6. What is the index of refraction of a medium?
7. Define: lens and draw a convexo-concave lens.
8. Define: spectrum and draw a ray of light passing obliquely through a piece of glass.
9. Define: compound microscope.
10. Define: Abbe condenser and illustrate the principle of a magnifying glass.

2.

1. In what ways may an object be examined miscroscopically?
2. Define: ocular micrometer.
3. Define: mechanical stage.
4. How is cedar oil used in microscopy and why?
5. Has the 2-3 objective a greater aperture than the 1-6?
   Has the 1-12 objective a smaller aperture than the 1-6?
6. How can the working aperture of a lens be made smaller?
7. Name the parts of an Abbe condenser.
8. What is the principal part of a polarizer and how is it made?
9. Define: analyser.
10. Of what use are the phenomena of polarization?

3.

1. Define: working distance of a microscope.
2. When focusing which power should be used first? Does it have a large or small front lens?

3. Name the steps in focusing with the high powers.
4. What may be the reasons why the object does not appear then?
5. What rules should be observed in returning the microscope to its case?
6. What should you do if the lenses are not clean?
7. Why should we not use the 1-6 objective without the cover glass on the object?
8. What is dark ground illumination, and what is its advantage?
9. Ultramicroscopy has enabled us to see objects of what extreme smallness?
10 What is the science of obtaining pictures of microscopic objects called?

4.

1. Distinguish between a positive and a print.
2. Distinguish between a positive and a lantern slide.
3. In what two ways can the projection lantern be used to represent microscopic objects?
4. What are the properties of ultra-violet light?
5. Give hygienic rules for microscopic work.
6. Give rules for drawing microscopic objects.
7. Define: focal plane and camera lucida.
8. Illustrate a Leitz drawing ocular.
9. Illustrate the principle of the smoked-glass camera lucida.
10. For what purposes are camera lucidas used?

5.

1. If 100mm. in the drawing cover two mm. on the stage micrometer what is the enlargement?
2. Define ocular micrometer and illustrate.
3. What is its position and why is it put there?
4. If five divisions of the ocular micrometer cover one-tenth mm., on the slide, how many microns does one division of the ocular micrometer measure?
5. What is the purpose of micrometry?

6. Give a complete definition of histology.
7. With what substances are life processes connected and what results from these processes?
8. What may a chemist learn from a study of cells?
9. Define microchemistry and give examples of its application.
10. How are objects examined microscopically?

6.

1. How are objects prepared for microscopical examination?
2. In what are tissues imbedded for cutting sections?
3. How may these sections then be cut and further prepared?
4. How may sections be mounted?
5. Name the general kinds of media which may be used?
6. Name the individual media which may be used.
7. Give directions for mounting small seeds.
8. Name the forms of cells.
9. Name the parts of the cell.
10. Define each.

7.

1. Define inulin and name drugs in which it is found.
2. Name alkaloids formed by cells. Of what use are they?
3. Of what substances are crystals formed by cells made?
4. Give microchemical test for some crystals.
5. Give a complete definition for crystals.
6. What dimorphous crystals did your text mention? Define dimorphous?
7. Name and illustrate the principal crystal forms.
8. How do crystals differ from cells in the manner of increasing in size? When do crystals form?
9. Define monoclinic crystals. They include what forms?
10. Define tissue and give examples.

8.

1. Define organ and name ten organs.
2. Name the kinds of plant hairs.

3. How can they be told from sclerenchyma fibres?
4. What structures convey the sap to the roots and where are they situated?
5. How can you tell a monocotyledonous from a dicotyledonous root?
6. Draw a cross-section of a root.
7. In longitudinal sections how can you distinguish roots from stems?
8. Name underground stems and their characteristics.
9. Name the functions of overground stems.
10. Illustrate the three types of stems.

9.

1. Name five parts which may be seen in a leaf section.
2. Define flower.
3. Define fruit.
4. What is the microscopical structure of fruits?
5. Define seed.
6. What is the microscopical structure of seeds?
7. What external characters may seeds have?
8. Define starch.
9. Of what importance is it to the microscopist?
10. State the variations in starches.

10.

1. From what and how does the spermatophyte develop?
2. Name the movements of plants.
3. Give the various names of the methods of reproduction.
4. What characteristics may differentiated cells have?
5. Define meristem and procambium.
6. Define phellogen and lenticel.
7. Define primary vascular bundle and closed bundle.
8. From what and how are roots developed?
9. Name the various plant tissues.
10. From what and how are the tissues of higher animals developed? Name the principal kinds.

LABORATORY EXERCISES.

Instructions to students: Work with care and neatness and you will soon acquire accuracy and rapidity. Do your own thinking and work.

Answer questions legibly and concisely and from your own observations if possible. Leave margins and do not crowd your work.

In making drawings locate certain points on the paper. Then draw lines connecting them, and upon this scaffolding lightly outline the object you are drawing. Compare with object to correct any false impressions you may have. Make drawings of the object, if possible, as seen with the naked eye, under low and high magnification. Get the correct proportions and if necessary practice first on another piece of paper or revise your drawings. Make magnified views large enough to show details clearly. Let your aim be not primarily to make something artistic or ornamental, but to illustrate principles and teach careful observation.

A drawing should show the shape of the object, the size, proportion, and relation of its parts. If possible represent its natural size, if not indicate the relation to the size of the object as $\times 500$ would mean that the dimensions in your drawing are 500 times those of the object. Often it is advisable to enlarge at a different place a certain part of a drawing, which fact should be clearly indicated.

Diagrammatic representations are often useful to illustrate certain fundamental structures of an object and should be made frequently. They show the relations of the parts, but need not represent their actual structure, shape, or size. Colored pencils or water colors are also very helpful by showing greater contrast. All drawings and their parts should be accurately and completely labeled.

Cleanliness is essential to good microscopical work. Be especially careful to have all optical parts clear and free from dust. That they may not become greasy or clouded by finger prints, wash your hands with soap. Do this also with your slides and cover glasses. On the clean dry slide we usually examine a small amount of material. If too much is taken

the view becomes obscured. Do not let any of the fluid get above the cover glass or below the slide.

Ex. 1.—Let a drop of NaCl salt solution slowly evaporate on a slide or watch glass. Examine without a cover glass, using the low power, and draw the crystals. These are inorganic substances and representatives of the mineral kingdom. Draw a few.

Ex. 2.—Put some compressed yeast in a dilute sugar solution or in the juice pressed from a fruit containing sugar. Leave this one day at a warm room temperature. Then examine the oval yeast cells, among which will probably be some forms which reproduced by budding. The very minute, spherical or elongated forms of bacterial cells may also be seen; also grains of starch, intermediate in size between the bacteria and yeast plants. These are representatives of the vegetable kingdom. Illustrate them.

Ex. 3.—Soak some beans or hay in water for a day at a warm room temperature and examine a drop of this or of water obtained from a stagnant pool during warm weather. In addition to the motile bacteria, which are plants, you will probably find other and larger bodies with independent motion. These animals may be uni- or multi-cellular. Draw some of these representatives of the animal kingdom.

Ex. 4.—Mount a little prepared wool in water and draw. What is wool? Mount another portion in picric acid, warm and wash with water. How are the fibers stained?

Ex. 5.—Add 5 cc. HCL to 95 cc. of Urine. After 24 hours decant and examine under the microscope a few of the crystals of uric acid which have settled to the bottom. Draw. Dissolve the rest in caustic potash. Carefully add excess of HCL. What is the result? To which of the three kingdoms in nature do uric acid crystals belong?

Ex. 6.—With a razor cut a thin slice from a potato. Mount in water. Examine with a low power and draw the cells with their contained starch grains. Examine a cell which has lost most of its starch, with a high power and draw it one inch

in diameter. Draw some of the tabular cells of the cork and of the cork cambium seen near the outside. What is the shape of the starch grains? How do they vary in size? Do they have any markings? Illustrate by drawing a starch grain one inch in diameter. When examined in polarized light, starch grains show a cross whose arms intersect at the hilum. What is the effect of adding iodine solution to starch?

Ex. 7.—Examine, draw and name characteristics of the starch of beans, wheat, and corn.

Ex. 8.—Apply gentle heat (50° C) to starch grains mounted on a slide in water. Examine to see what change has occurred. What change has taken place in the starch grains of bread? Examine starch from a germinating seed. Illustrate the corrosion of the grains.

Ex. 9.—In a cross-section made from a corn seed previously soaked in water, draw the capsule, seed coat, aleurone layer (rectangular cells filled with aleurone grains) and starch layer.

Ex. 10.—Mount a thin cross-section of castor oil bean in water. The globules of oleum ricini will vanish on the addition of alcohol, which is a solvent of fat. What is the effect of treating a fresh section with tincture of alkanna? From a section mounted in glycerine draw the fat globules, the large spheroidal aleurone grains and other proteid matter. After a while the angular crystalloid appears. At one side of the aleurone grains next to the crystalloid will be seen the small spherical globoid. What is the effect of adding dilute KOH solution; iodine solution; saturated solution of picric acid; Millon's reagent?

Ex. 11.—Examine sections of taraxacum root which were in alcohol a few days, for the chief contents of the parenchymatous cells, the lumps of inulin. They are spheroidal masses with a radiating structure. Examine with polarized light. What is the effect of adding iodine solution; of gently warming a section in water?

Ex. 12.—Draw the crystals in the outer scales of an onion bulb. What effect on them has acetic acid; dilute HCl? Of what are they made?

Ex. 13.—Illustrate and describe a moss leaf. Look for division of chloroplasts. What is the effect of adding alcohol; iodine solution?

Ex. 14.—In a longitudinal and cross-section of corn, oak or willow stem study the bast fibers. Illustrate.

Ex. 15.—In cross and surface views of the epidermis of tradescantia leaf examine the guard cells (stomata surrounded by two large and two small cells). What structures do you see in the cell? Draw.

Ex. 16.—Examine the hair just back of the growing point of a root tip. Note particles of dirt adhering. Compare with a root which is germinated in moist air or water. Draw and explain. Find a root cap which consists of larger cells loosely arranged at the apex of the root. Back of the tip are the smaller and more densely arranged cells of the growing point.

Ex. 17.—Examine a cross-section of a one-year old twig of a pine tree and in your drawing indicate the bark, wood and pith, medullary rays and resin canals. Compare with a two-year old twig. How are the annual rings formed? The medullary ray cells extend radially, the fusiform wood cells longitudinally. Some of the latter known as tracheids have their funnel-shaped openings appearing in the form of two concentric circles, the bordered pits. Stain with haematoxylin or fuchsin. Examine a radial longitudinal section. Examine a tangential section in which the medullary rays are seen grouped together between the tracheids. Draw.

Ex. 18.—Examine and compare with the foregoing the wood of a dicotyledonous plant. Draw some of the large pith cells, medullary ray cells and cells with spiral thickenings. What is the effect of adding iodine? Draw the cambium and bast with the sieve tubes, companion cells, collenchyma, crystals and other things they may contain, being sure to label everything.

Ex. 19.—Examine a cross-section of the root of a dicotyledonous plant and notice how many bands of xylem radiate from the center. Compare with the arrangement in monocotyledonous plants. Compare with a cross-section of the fern rhizome.

Ex. 20. Mount a few fragments of flax in a drop of water. Groups of bast fibers are seen to make up the threads. Carefully tease them apart with needles. Cover, examine and draw. The narrow central cavity contains the remains of the granular protoplasm. Irrigate the preparation with an iodine solution. After it is absorbed, nearly dry the flax with filter paper and then irrigate with sulphuric acid solution (conc. H_2 SO_4, three volumes, water 1, glycerine 2). The cellulose reaction manifests itself by the fibers assuming a blue color.

Ex. 21. Put a few threads of raw cotton in a drop of alcohol. When most of the alcohol has evaporated add a drop of water, cover, examine and draw. Treat as stated above for flax. Or the cellulose reaction may be obtained by irrigating a fresh preparation in water with chlorzinciodine. To distinguish from animal wool, mount a few threads in a saturated aqueous solution of picric acid, warm for a few moments and cool. Cotten is not stained yellow while animal wool is.

Ex. 22. With a clean finger rub the inner side of your cheek and then touch a slide. Cover the saliva. What does it contain? Illustrate. Add a drop of fuchsin or methylen blue. What is the effect?

Ex. 23. In a drop of milk notice the globules of fat. Draw and describe milk.

Ex. 24. In a drop of fresh human blood notice how the red corpusles form "rouleaux" looking like rolls of coins. The white corpuscles are fewer and larger. Describe and illustrate the blood.

Ex. 25. Put a small piece of muscle (fresh meat) in a strong solution of KOH. The fibers of which it is composed are then to be teased apart with needles and examined. Draw some of these cross-striated, polynuclear, cylindrical cells.

Part II.

MICROSCOPICAL EXAMINATION OF DRUGS.

1. **Aloe**—*Aloes.*.

Examine and describe aloe, the inspissated juice of the leaves of Aloe vera and other species of Aloe. It can be broken into transparent pieces which seem to be crystals but when examined under the microscope prove not to be crystals. As the small fragments of aloe rapidly dissolve in water, examine in glycerine or dry, by crushing a small piece on the slide and throwing off the large pieces. Draw.

2. **Althaea**— *Marshmallow.*

The pieces of the dried root of Althaea officinalis deprived of the outer corky layer may be easily examined microscopically by holding them in pith or cork and cutting sections dry. Examine in water on a glass slide. The dark xylem and cortical cells are filled with starch grains, the broad light colored cambium zone with protoplasm. Light spots in the xylem and cortex indicate the mucilage cells, and in the xylem also tracheal tubes, which characterized by their thick yellowish walls usually lie in groups. The thin-walled mucilage cells are singly and in pairs. To clear the section add KOH solution, which gelatinizes the starch. The crystals of calcium oxalate can then be seen in the transparent tissues. Let another section dry in a drop of phloroglucin solution. Add a drop of dilute HCL, cover and examine the lignified cells and tubes which first become red inside and then outside the cambium zone.

3. **Amygdala amara et dulcis**—*Bitter and Sweet Almond.*

Examine the ripe seed of Prunus Amygdalus. Scrape some of the epidermal cells on to a slide and examine in a drop of chloralhydrate solution. Draw.

4. **Anisum**—*Anise.*

The ripe fruit of Pimpinella anisum is examined by imbedding several upright in a softened paraffin block. Examine the sections in water or chloral hydrate. The external surface is seen to be ribbed and bears many granular unicellular

hair. A round bundle of sclerenchyma fibres is within each rib. Between the latter lie four to six yellowish oil glands.

The brownish powder examined to chloral hydrate shows furthermore the large number of small regular thin walled cells or their fragments from the endosperm and embryo with oil globules and proteid granules, reddish brown parenchyma tissue enclosing the vitae, rosette crystals of calcium oxalate, inner epidermis of pericarp, some short porous sclerenchymatous and elongated cells from the carpophor and peduncle. The numerous trichomes are most characteristic.

5. **Arnica**—*Arnica Flowers.*

The dried flower heads of Arnica montana bear many yellow ligulate ray-florets and more shorter tubular disk-florets. The pentagonal ovaries are surrounded by double hair which point upwardly. Examine in air with low power. The long and hairy pappus consists of multicellular bristles which have upwardly projecting simple pointed hair. Spherical pollen grains (25-35μ) are often seen.

6. **Calamus**—*Sweet Flag.*

Examine and draw a section of the dried rhizome of Acorus calamus in water. Yellowish fibro-vascular bundles are near the inner sheath. The spongy consistency of the parenchyma is due to the large air cells found in all aquatic plants. These intercellular spaces are surrounded by a network of cellular elements filled with starch and one cell thick. At the nodes are clear secretion cells. The volatile oil in the parenchyma is most abundant in the cortical layer.

7. **Cinchona**—*Peruvian Bark.*

Moisten a cross section of a quill of the dried bark of Cinchona officinalis or other species of Cinchona with a drop of water, cut thin sections and mount. To clear, add a drop of KOH solution to the edge of the cover glass. Draw, labeling the dark cork layer, the medullary rays, sclerenchyma fibres, laticiferous tubes and the dark cells of sandy crystals of calcium oxalate. The latter named will be more readily found by polarization. The bast fibres appear as clear round circles 70μ

in diameter. To learn more about them macerate a piece of the drug about 50x1 to 2mm by boiling three minutes in concentrated HCL to which a few grains of $KCLO_3$ have been added. This separates the cells, which can then be easily teased apart. Pour the drug with the boiling acid in a glass of water, rinse the drug and on a slide separate the cells with needles. To color the bast fibres red add a drop of phloroglucin solution and let dry. Then add a drop of dilute HCL, cover and examine.

8. **Cinnamomum Saigonicum**—*Saigon Cinnamon.*

Examine the powder of this dried bark of the stem and branches in KOH solution. Notice the nearly isodiametrical bright yellow unequally thickened stone cells of the outer cortex and the fewer pieces of very thin walled cork cells; also the bright yellow sclerenchyma fibres and the dark brown secretion cells. The alkali has changed the starch into round hyaline bodies.

9. **Colchici Semen**—*Colchichum Seed.*

Examine the light brown powder of the seed of Colchicum autumnale in chloral hydrate. It consists of fragments of the testa and of the white endosperm and embryo. The endosperm cells are characterized by the large number of fat droplets they contain, proteid granules and the round pores in their thick walls.

10. **Crocus**—*Saffron.*

To examine the stigmas of Crocus sativus soak the drug one hour in cold water or one minute in boiling water. Using a magnifying glass and needles unfold a style, which may have three stigmas, in a drop of water on a slide. Notice how the stigma converges below, where a small vein arises, branches dichotomously and ends in about twenty branches near the papillae where the pollen grains may be seen. Draw.

Saffron is often adulterated with the lighter colored styles and with florets of other flowers. These may be detected by dropping them in water and examining for their characteristic forms. Mineral adulterants will subside to the bottom and calcium carbonate can be detected by the addition of an acid.

11. **Cubeba**—*Cubeb.*

Select one of these dried unripe fruits of Piper cubeba having a long stem so that it can be held. Cut off half the fruit with a scalpel. Then without moistening cut sections with a razor and examine in a drop of water. The inner wall of the shell consists of a double or triple layer of light colored radially elongated stone cells. Another layer of stone cells but usually only one cell thick is just below the epidermis. Between these two layers are the parenchyma cells filled with starch. Along the middle of the parenchyma layer the large ovoid secretion cells lie scattered. Add KOH solution to the side of the cover glass. Draw.

Mount some of the dark powder in KOH solution. Besides the above mentioned elements notice the elongated or isodiametric but comparatively thin-walled stone cells from the stem and the regular and very small parenchyma cells from the embryo. The parenchyma of the endosperm has small starch grains and oil globules.

12. **Digitalis**—*Foxglove.*

The dried leaves of Digitalis purpurea may be examined by putting the scrapings from the under side in a drop of water or chloral hydrate solution. Only the lower epidermis contains stomata. The hair consists mostly of 3-5 cells. The nonglandular hair are granular and have markings, the less abundant glandular hair are smooth. One kind is large with a multicellular stalk while the other is small with a unicellular stalk and a two celled head. After boiling some leaf fragments for ten minutes in water, crush one in chloral hydrate solution and separate the parts with needles. Thus the absence of crystals may be demonstrated. Draw.

13. **Frangula**—*Buckthorn.*

Mount a cross-section of the dried bark of the stem and branches of Rhamnus Frangula in KOH solution and notice that the yellow color is changed to red, especially the bent medullary rays of the inner bark which are 1 to 3 cells wide. The sclerenchyma fibres are arranged in tangential rows surrounded by cells each of which contain calcium oxalate. Ex-

amine likewise an inner tangential section of a piece of bark which has been in boiling water five minutes, and draw a medullary ray which is 10 to 25 cells high, and the surrounding cells. Continue cutting tangential sections until you get to the layer of sclerenchyma fibres. These sections show best the crystal-bearing fibres. Notice absence of stone cells. Draw.

14. **Gentiana**—*Gentian.*

The dry rhizome and roots of Gentiana lutea are yellowish-brown, with transverse marks and longitudinally wrinkled. Place a section in water and add iodine solution. Starch is seldom seen and the crystals of calcium oxalate are very small. The xylem contains in addition to the tracheal ducts also sieve tubes which, however, are difficult to find.

In the orange-brown powder we again notice the absence of starch grains and stone cells. The presence of crystals of calcium oxalate can be determined by polarization. Large and empty parenchyma cells and a few large ducts, brownish cork, thick-walled collenchyma and wood fibres may be seen.

15. **Granatum**—*Pomegranate.*

The bark of the stem of Punica Granatum has an outer yellowish-brown longitudinally wrinkled surface with grayish patches and small lenticels. The inner surface is light yellow, smooth and finely striated. The bark of the root is yellowish-gray to brown on the outside, marked with patches of cork; the inner surface is smooth and yellowish with irregular brownish blotches. To distinguish pomegranate from other barks with which it may be adulterated steep in water and rub the inner bark on paper. Ferrous sulphate should turn the yellow stain blue and nitric acid, rose-red. Section the moistened end of a piece of bark and examine in water. Observe the small starch grains in the cortical, parenchyma, the striation of the inner part due to the one cell wide medullary rays between tangential rows of crystal-bearing cells and the large sclerenchyma cells. Add KOH solution. An orange color results Absorb with filter paper and add water on the opposite side of the cover glass until the section is clear. Draw.

16. **Hydrastis**— *Golden Seal.*

The dried rhizome of Hydrastis canadensis is examined by first soaking a piece five to six hours in water and cutting cross-sections. A thin section of the outer part examined in water shows a corky layer a few cells thick, of quite large, oblong, brownish cells. Below this are the cortical cells filled with spherical grains of starch three to twenty microns in diameter. Some cells contain a bright yellow resin. In longitudinal sections mounted in KOH solution, notice the short segments in the porous tracheal tubes and the oblique pores in the woody fibres. Next cut a cross-section from a dry piece of the rhizome. Add a drop of concentrated HNO_3, cover and look for yellow acicular crystals of berberinnitrate, usually in radiate groups. Do not let any of the acid touch the objective.

17. **Hyoscyamus**— *Henbane.*

The dried leaves of Hyoscyamus niger are best examined by crushing a piece of a leaf which has been boiled about five minutes. Spread some of this material in a drop of chloralhydrate and examine. Notice a large number of multicellular hair, chlorophyll tissue, epidermis and parts of veins, especially small spiral tubes. Small single or double crystals are in the mesophyll cells.

The dull green powder examined in chloralhydrate shows these crystals more readily. Look for the heads of the glandular hair, stomata, various trichomes and spongy parenchyma The presence of pollen grains, fragments of anthers, and of cells which are colored violet by the chloralhydrate shows that the flowering tops were also used in making the powder

18. **Ipecacuanha**— *Ipecac.*

Pieces of the dried root of Cephaelis ipecacuanha are soaked in water for three to six hours. Put in pith and cut sections up to the xylem and examine them in water or dilute glycerine Below the brownish red cork layer is a thick stratum of cortical parenchyma filled with starch grains. Some of the cells have bundles of calcium oxalate raphides in place of the starch cells. We next examine the wiry xylem which contains little

or none of the alkaloids, emetine, cephaeline and psychotrine which are in the other parts. Boil pieces of xylem in concentrated HNO_3, to which a few crystals of potassium chlorate have been added, until the parts separate. This will be less than five minutes. Pour in a glass of water, rinse, take out a piece, crush it and tease apart with needles and examine in water. Notice the spindle-shaped fibers and the more bluntly terminating tracheids with simple oblique or bordered pores, and communicating round openings near the ends.

Examine the dark yellow powder in water. The single or two-to-four-compound roundish grains of starch should not be more than fourteen microns in diameter in Rio ipecac while in the Carthagena ipecac they are slightly larger. Besides the parenchyma containing starch other cells have the 20 to 40 μ long bundles of calcium oxalate raphides. Starch grains are sometimes also in the tracheids which have simple oblique or bordered pores. Clear the preparation with a drop of KOH solution, examine and draw.

19. **Jalapa**—*Jalap.*

The dried tuberous root of Exogonium purga is to be cut or sawed transversely. The section is brownish and resinous as the drug was dried at a high temperature. It shows many concentric dark lines and small irregularly distributed curved lines (from the cambium). These have formed toward the inside tracheal tubes, toward the periphery, sieve tubes and resin cells. Wetting the surface with water shows these parts more clearly. Cut a section containing one or more of the circles. Mount in KOH solution to remove the numerous starch grains. Outside of the secondary cambium is the parenchyma, containing the large yellowish resin cells, and very few sieve tubes. Within the cambium circle is a radially arranged parenchyma about a central group of tracheal tubes surrounded by small thick-walled cells. Smaller secondary groups like them may surround the central group. A study of the internal structure enables us to detect adulterations. Draw.

Examine the grayish-brown powder. The thin-walled cortical parenchyma cells contain aggregate crystals of calcium oxalate, single and one to three compound starch grains, some-

times gelatinized. Brownish cork cells may be seen, a few tracheids, porous tubes, laticiferous ducts and yellowish resin cells.

20. **Linum**—*Linseed.*

The ripe seed of Linum usitatissimum is held in cork and cross-sections then cut. Examine these in water. The swollen epidermis consists of hyaline mucilage cells with very thin radial walls and thick outer and inner walls. The presence of mucilage which cannot be seen is made evident by the addition of India ink solution. By adding iodine solution we find that the regular parenchyma cells of the endosperm and embryo which are rich in oil contain no starch. In the brown powder notice the thin-walled parenchyma cells containing aleurone and oil globules, also the sclerenchyma of small yellow stone cells. The mucilaginous epidermal cells swell up in water. Apply the India ink and iodine tests.

21. **Myristica**—*Nutmeg.*

The kernel of the ripe seeds of Myristica fragans shows on section a mottled appearance, due to the brownish perisperm penetrating into the yellowish endosperm. This easily cut surface has a waxy luster. Examine and draw a section of it. The endosperm parenchyma contains oil, starch, aleurone and some pigment cells. The cells of the outer perisperm contain rounded cells, brown pigment and prismatic, sometimes tabular crystals of potassium bitartrate, the cells of the perisperm folded between the endosperm are polygonal and contain numerous large oil cells. Examine a section in iodine solution. Heat another section on the slide so that the water boils. Cool and add tincture of alkanna. This will more readily color red the exuded fat than that contained within the cells.

22. **Nux Vomica**—*Nux Vomica.*

The dried ripe seed of Strychnos nux vomica is examined by cutting a large seed transversely in two; wet the surface with water, cut and mount thin cross-sections in iodine solution. The testa consists of two layers. It is covered with solid hair consisting of closely and obliquely packed together pali-

sade-like cells, each resting on a characteristic foot-like expansion below. Their distal ends split apart. The cells of the horny endosperm have thick cell walls and get larger as we go farther from the surface, where they form a kind of palisade They contain no starch, but oil globules and aleurone. Another section mounted in fuming HNO_3 turns orange-yellow. The alkaloid is tested for with $H_2 SO_4$, which colors it blue.

Examine the yellowish-gray powdered drug in iodine solution.

23. **Pilocarpus**—*Jaborandi.*

In the leaflets of Pilocarpus Jaborandi, the many light spots are due to intercellular reservoirs near the upper epidermis in which are drops of a yellowish oil. Boil a leaf, fold it repeatedly and cut sections. Examine in chloral hydrate. The palisade layer is only about one-fifth of the thickness of the leaf, the spongy parenchyma occupying most of the space. Many crystals of calcium oxalate may also be seen. Draw.

24. **Quassia**—*Quassia.*

Examine the wood of Picrasma excelsa (known commercially as Jamaica Quassia) and of Quassia amara (Surinam Quassia). The cross-section of the yellowish-white wood of the former species shows medullary rays two to five cells broad, separated by two to five tangential rows of woody parenchyma cells containing sometimes large solitary oxalate crystals. Solitary or groups of two to five tracheal tubes lie adjacent to the wood parenchyma. Between these various parts are the cross-sections of the slightly thickened sclerenchyma fibres, which are of a cylindrical spindle shape. This can be seen in a longitudinal tangential section which also shows that the medullary rays are usually ten to twenty-five cells high, while in Quassia amara they are five to twenty cells high, and only one, seldom two cells broad. The latter wood also has no oxalate crystals. The chips of quassia which are usually employed in pharmacy may be examined similarly after determining which is the longitudinal tangential and which the cross-section side. We are aided in this by observing with a lens the direction of the fibres. Cutting around a piece in the

direction in which the fibres run we cannot miss the tangential section. Some pieces may show lines running at right angles to the fibres. These lines are the medullary rays in a radial longitudinal section. Cutting at right angles to them gives tangential sections, while if we cut at right angles to the direction of the woody fibres we get cross-sections of the wood.

Examine some of the light yellow powder in water. Observe the large ducts pierced by many pores, the oxalate crystals, fragments with yellow resin masses, not seen in all preparations, especially of the Jamaica Quassia, and derived from the outer parts where the resin ducts run. Only in powder of Quassia amara and of bark tissues are stone cells found.

25. **Quillaja**—*Soapbark.*

Scrape some of the dried bark derived from the periderm of Quillaja Saponaria or put some fine sawdust obtained from it on a slide, examine directly with a low power and measure some of the numerous elongated prisms of calcium oxalate. As the bark is brittle, in order to make a cross section, boil it first in water. Examine a section under the low power, notice the scattered dark patches of bast fibres, the elongated cells of the medullary rays and the parenchyma cells containing fragments of crystals. Observe the absence of cork cells. Draw.

26. **Rhamnus Purshiana**—*Cascara Sagrada.*

The dried bark of Rhamnus Purshiana is prepared to be examined by exposing thin small pieces to moist air for 12 to 24 hours. Embed in pith and put the transverse sections in alcohol. Transfer to water on a slide, add glycerine, examine and draw. The outside layer of cork may have a whitish cover of lichen. Stain sclerenchyma red with phloroglucin and HCL. The bast fiber groups stretch tangentially from one medullary ray to another. Similarly examine and draw radial sections. Each group of bast fibers is surrounded by crystal-bearing fibers, each cell of which contains a calcium oxalate prism. Identify medullary rays and sieve tubes. The oblique sieve plates may be stained with corallin-soda.

Examine the yellowish-brown powder in water or dilute glycerine. Moisten another portion of powder with alcohol

and when nearly dry add chloral hydrate, which rapidly clears the tissues. Besides the above named elements notice the stone cells of about 50 μ which are absent in Frangula. Aggregate crystals are also present. The powder is colored orange by the addition of an alkaline solution, while Rhamnus Californica turns deep red.

27. **Salvia**—*Sage.*

When the dried leaves of Salvia officinalis are examined with a lens, large, spherical, light colored, sessile, glandular hair are noticed. The dense hairy covering of the leaves may be seen better by scraping them and examining the material which comes off in water. Both upper and lower sides of the leaves contain thin, long, rather thick-walled, air filled hair, each consisting of 1 to 5 cells. There are furthermore two sizes of glandular hair on stalks with a one or two celled head. To see the smaller hair cut sections of the moist leaf in pith.

28. **Sarsaparilla**—*Sarsaparilla.*

Examine microscopically a cross-section of the dried root of Smilax officinalis, or of some other species of Smilax. A thin easily removable epidermis covers a thick white layer of cortical parenchyma. The brown circle inside of this is the layer of endodermal cells. These examined under the microscope show thickened walls and a horse shoe shape. The cells of the cortex contain starch granules (or paste if gelatinized by heat) and sometimes calcium oxalate raphides. The medulla at the center of the section is surrounded by the xylem. Draw.

Examine the grayish-brown powder in water. The small spherical starch grains are single or aggregated. Epi- and endodermal tissue is brown. Bundles of raphides may be seen in the parenchyma. Parts of the elongated woody cells and large reticulate, spiral and annular ducts may also be seen.

29. **Scilla**—*Squill.*

Boil a few pieces from the bulb of Urginea Maritima five to ten minutes in water, and pull off the epidermis of both sides. Look for stomata or breathing pores. Draw a stoma with its guard cells and surrounding epidermal cells.

Examine the yellowish squill powder in water or dilute glycerine. Besides the epidermis seen look for and draw pieces of spiral tracheal tubes, bundles of acicular calcium oxalate crystals, the raphides. These on the addition of iodine solution remain colorless while the other parts are stained yellowish with the exception of the few small starch grains which color blue to black.

30. **Senna**—*Senna.*

The dried leaflets of Cassia Acutifolia (Alexandria senna) and C. angustifolia (India senna, or when cultivated Tinnevelly senna) are examined by making cross-sections and surface sections of both sides of the leaf. To soften them for this purpose boil them in water a short time. Fold one of the leaflets a number of times and cut thin sections in pith. Examine in chloral hydrate. To get the surface view, stretch another leaflet about the left index finger, cut off a flat piece and examine in water. Stomata are on both sides of the leaf, roundish in Alexandria and more elongated in India senna. The epidermis of both sides consists of polygonal cells and bears unicellular, thick-walled, spinous hair, abundant in Alexandria but scarce in India Senna. Below each epidermis is a layer of palisade cells with wavy outlines. Between these two layers are roundish mesophyll cells and aggregate crystals of calcium oxalate. Near the veinlets the cells of the middle layer are elongated. Illustrate the various parts.

The light green powder of the drug shows up well in chloral hydrate. When the powder has been adulterated with the leaves of Castanea dentata it turns blue on the addition of ammonio-ferric alum.

31. **Strophanthus**—*Strophanthus.*

The ripe seed of Strophanthus Kombe is examined by embedding it longitudinally in pith or cork and mounting the sections in chloralhydrate. The straight embryo and the endosperm are white, the testa with its long unicellular hair are brown. The latter rise from the middle part of the large epidermal cells which have thickened convex radial walls. Nu-

merous oil globules are in the cells of the endosperm and embryo. To find the few if any starch grains which may be present, and should be round and not exced 8 μ, add very dilute iodine solution. Draw this and also a cross-section showing the flat cotyledons. Concentrated $H_2 SO_4$ added to a section colors it green. (The test for strophanthin.)

Examine and draw the various elements found in the dark brown powder.

32. **Uva Ursi**—*Bearberry.*

The dried leaves of Arctostaphylos uva ursi are prepared for sectioning by boiling some fragments a short time in water. Free hand sections may be improved upon by fastening a piece of the drug on a block with paraffin. Cut sections of both sides of the leaf parallel to the surface and examine in water. The upper epidermis consists of polygonal cells. Stomata are on the lower side only and lie depressed beneath the surface. The crescentic cells surrounding the pores are contiguous cells to the guard cells. The latter are hidden from view by a membrane with jagged inner edge interposed between them and the former. Make free hand cross-sections from the soaked or dried leaves so as to include the midrib, above which there is a groove. Or embed first in pith. Examine in chloral hydrate and notice that while the mesophyll consists of similar, slightly elongated, thin-walled cells, the parts above and below the midrib have smaller, thick-walled cells, which contain solitary prisms of calcium oxalate, especially on the lower side. Draw.

Look for these elements in the greenish-brown powder mounted in a drop of chloral hydrate. The stomata are the best means of identifying the drug. Also look for the short unicellular hair.

33. **Valeriana**—*Valerian.*

The root of Valeriana officinalis is prepared for examination by being soaked a few hours in water. Examine thin sections of a young root. Outside of the central xylem, is the cortex whose cells are filled with starch. This is surrounded by the hypoderm, a layer of large cells which alone contain

the odorous secretion of the drug. This is covered externally by the small-celled epidermis. Draw.

34. **Veratrum**—*Hellebore.*

The dried rhizome of Veratrum viride or V. album is examined by getting an exact cross-section and cutting a section from the part containing the wavy brown endodermis which separates the cortex from the central cylinder. Fibrovascular bundles pass through both, especially the latter. The central part of the bundles consists of thin-walled phloem. This is surrounded by thick-walled xylem cells whose ducts run curved and not straight. Bundles of calcium oxalate raphides are in some of the parenchyma cells. The irregularly thickened walls of the endodermal cells give them a horse-shoe shape.

35. **Zingiber**—*Ginger.*

The dried rhizome of Zingiber officinalis shows a small cortical layer compared with the central cylinder. Both are whitish and dotted with fibrovascular bundles and numerous small orange colored oil and resin cells. These can easily be seen by cutting a section from the dry drug and making the numerous starch grains which are present transparent by mounting in KOH solution.

In the yellowish-brown powder look for and measure the characteristic starch grains. These oval to elliptical bodies are in the large parenchyma cells. The ducts are also large, the bast fibers long and thin-walled. The oil and resin cells have suberized walls. Cork cells are found in African ginger.

APPENDIX A.

Cell Contents and How to Determine Their Presence.

Name	Definition Constitution	Properties	Stained
Aleurone Grains	Protein matter as small rounded particles. In seeds consist of crystalloid, globoid,* calcium oxalate* and ground mass.	The parts are brought out more clearly by iodine water. The crystalloid is dissolved by .5% KOH solution, the globoid by a 1% acetic acid solution.	Bright yellow by picric acid Yellowish-brown by iodine.
Alkaloids	Nitrogenous vegetable compounds of basic and alkaline character. Chief constituents of the active principles of the vegetable drugs.	Solid, crystalizable and non-volatile or liquid and volatile. Usually soluble in alcohol, ether and chloroform Quinine salts in dilute solution have a blue fluorescence.	Usually intensely by HNO_3, H_2SO_4 and Chlorine water. Reddish brown even by very dilute iodine solution. (Strophanthine) greenish by H_2SO_4.
Calcium Carbonate	$CaCO_3$	Dissolved with effervescence by acetic and by hydrochloric acid. H_2SO_4 produces in addition acicular crystals of calcium sulphate.	
Calcium Oxalate	CaC_2O_4	Insoluble in water and in acetic acid. Soluble in HCL without effervescence. Soluble in H_2SO_4 with formation of acicular crystals of calcium sulphate.	
Cell Wall (Cellulose)	$C_{12}H_{20}O_{10}$	Insoluble in most usual solvents. Dissolved by Schweitzer's reagent and decomposed by certain bacteria.	Blue or violet by chlorzinciodine. Blue-with I. followed by H_2SO_4.
Cell Wall (Lignified)	$C_{19}H_{24}O_{10}$? A modified Cellulose.	Swells and dissolves in strong H_2SO_4, especially if gently warmed.	Yellow or brown by chlorzinciodine. Bright yellow by aniline chloride or sulphate. Bright red by phloroglucin and HCl.
Cell Wall (Suberized)	Cork-like	Resists the action of concentrated H_2SO_4.	Yellow or brown by chlorzinciodine. Yellow by strong KOH solution.
	*May be absent.		

Cell Contents and How to Determine Their Presence—Cont'd.

Name	Definition Constitution	Properties	Stained
Cytoplasm	Substance of cell between nucleus and cell wall. Consists of spongioplasm and hyaloplasm.	(See Protoplasm)	By acid dyes as eosin, picric acid, acid fuchsin, congo red.
Inulin	$C_6H_{10}O_5$. A vegetable carbohydrate found in roots of elecampane, chicory, dahlia etc.	Occurs as highly refractive solution, amorphous and easily soluble in water or crystalline and nearly insoluble in water. Sphere-crystalloids form when the plant was preserved in alchool.	Yellow by iodine solution.
Mucilage	A viscid substance formed by a change in the contents of the cell or cell wall.	Swells in water. Insoluble in alcohol and glycerine. Soluble in ammoniacal solution of cupric oxide.	Blue by chlorzinciodine and methylene blue. Yellowish by subacetate of lead.
Nucleus	The essential part of a typical cell. (See Protoplasm)	Regulates the activities and reproduction of the cell. Fixed by alcohol, acids etc.	By basic dyes as methylene blue, gentian violet, fuchsin, safranin.
Oil, Fixed	Fats or Esters. Contain C, H, and O.	Greasy. In globules. Saponified by ammoniacal potash. Insoluble in water. Not readily soluble in alcohol. Soluble in ether-alcohol, chloroform, benzin, carbon disulphide and acetone.	Pink by tincture of alkanna. Brownish or black by osmic acid.
Oil, Volatile	Liquids of oily consistency of terpenes ($C_{10}H_{16}$) Most contain O, a few N, and a few S.	In globules. Not Saponified by ammoniacal potash. Slightly soluble in water. Soluble in alcohol.	Red by tincture of alkanna. Red by fuchsin (sometimes).
Proteins	Contain C, H. O and N, usually S also and sometimes P or other elements.	Globulins are insoluble in pure water and dilute acids but soluble in dilute salt solutions. The alcohol-soluble proteins of cereals are cohesive. Many occur in crystalline form free in the cytoplasm or as part of aleurone grains.	Yellow or brown by iodine solution. Yellow by picric acid. Yellow by potash after nitric acid. Red by Millon's reagent.

Cell Contents and How to Determine Their Presence—Cont'd.

Name	Definition Constitution	Properties	Stained
Protoplasm	A jelly-like living substance, changeable composition. Has large unstable molecules of proteins. Consists of cytoplasm, nuclei and plastids.	Assimilation, growth, reproduction, secretion, irritability and motility. Slimy, granular semi-fluid. Coagulated by alcohol, acids, formalin and $HgCl_2$.	By haematoxylin, carmine and aniline dyes
Resin	Oxidized terpenes. In crude essential oils or occur as exudations. They are amorphous mostly vitreous bodies.	Occurs in irregular solid masses, soluble in alcohol, strong alkalies, ether, chloroform and oils but precipitated by water. A saturated solution of copper acetate turns it green.	Red by tincture of alkanna
Starch	$C_6H_{10}O_5$. A carbohydrate in nearly all plants above the fungi. Occurs in granules or grains often characteristic of the plant in which they occur.	Insoluble in cold water, swells when boiled with water, Swollen by caustic potash. A faint blue color may be produced when dry starch and I. are triturated together. Triturating with water produces a deep blue color. This disappears on heating the solution but returns on cooling.	Blue by iodine solution
Sugars	Carbohydrates as cane-sugar, $C_{12}H_{22}O_{11}$ Glucose, $C_6H_{12}O_6$ Levulose, Maltose etc.	Sweet. Widely distributed. Obtained from cell-sap by evaporation or may be crystallized out by alcohol. Dextrose crystallizes in needles. With other principles it forms glucosides. Sucrose crystallizes in monoclinic prisms or pyramids.	Glucoses give a reddish precipitate with Fehling's solution.
Tannin	Astringent principle belonging to the class of phenol acids. Contains no N.	Amorphous. Is precipitated in plant cells by copper acetate. May be present up to 70% (Chinese galls). Braemer's reagent gives brownish precipitate.	Greenish or bluish-black with iron salts.

APPENDIX B.

REAGENTS OF GENERAL UTILITY.

Absolute Alcohol.—This is a good medium for hardening and fixing plant and animal tissues. The organs used should be fresh and cut into small pieces. Change the alcohol every day for three days.

Acetic Acid.—Should contain about 36% of absolute acetic acid. It dissolves calcium carbonate but not calcium oxalate.

Alcohol.—Commercial alcohol contains about 95% of absolute alcohol. It removes air from sections of dried tissues, dissolves resin, volatile oil, tannin, chlorophyll, etc.

Alkanna, Tincture of.—Extract the coloring matter from the roots of Alcanna tinctoria with absolute alcohol, then add an equal bulk of distilled water and filter.

Chloralhydrate.—Dissolve 50 gr. chloralhydrate in 20 cc. water.

Corallin-soda.—Dissolve 30g. sodium carbonate in 70g. water. To a little of this solution add enough corralin to produce a bright pink color. The mixture must be freshly prepared.

Glycerine.—This may be used for temporary or even permanent mounting when ringed with varnish.

Glycerin-jelly.—Soak 30g. gelatin in 90cc. water for an hour. Heat to near boiling point and add 120cc. glycerin, filter while hot and add four drops of carbolic acid.

Iodine Solution.—Add 2g. Potassium iodide and 1g. iodine to 300g. of water.

Phloroglucin.—Add 1 to 2g. Phloroglucin to 100cc alcohol.

Potassium Hydrate.—Dissolve 33g. KOH in 67g. water. It is used to induce swelling of refractory cell walls and to disclose the structure of collapsed tissue. A 5% solution is employed as a clearing agent, a 1% solution shows the markings on starch grains and a .3% solution is used to dissolve aleurone grains.

APPENDIX C.—MEMORANDA.

HISTOLOGICAL SCHEDULE.

To Fix and Harden Material.

1. Put a small piece of the tissue in Flemming's or some other fixative about ½ to 1 day.
2. Wash in water ¼ to 1 day.
3. In 15, 35, 50, 70, 85, 95, 100% alcohol, 6 to 24 hours each.

A. PARAFFIN METHOD.

I. To Imbed.

1. Remove tissue from 100% Alcohol and put in xylol, 6 hours.
2. Paraffin-xylol, 1 day.
3. Melted paraffin, 1 day.
4. Imbed in paraffin.
5. Attach to a block and cut sections 10 microns thick.

II. To Stain and Mount Paraffin Sections.

1. Put a few drops of albumen water on a clean slide. Place the section on this and warm to straighten out folds. Absorb any excess water with filter paper.
2. Place slide in warm oven several hours.
3. Remove paraffin by immersing in xylol.
4. Absolute Alcohol, 1 minute.
5. 95% Alcohol, 1 minute.
6. 70% Alcohol, 1 minute.

6a. (In bleaching solution about 20 minutes if tissue was completely fixed and therefore blackened in Flemming's fixative. Rinse in water.)

7. Stain, 5 to 30 minutes.
8. Rinse in clear water, 5 minutes.
9. Acid alcohol, about 1 second.
10. 70% alcohol, 1 minute.
11. 95% alcohol, 30 seconds.
12. 100% alcohol, 30 seconds.
13. Xylol, 1 minute.
14. Mount in Canada Balsam.

B. CELLOIDIN METHOD.

I. To Imbed.

1. Remove tissue from 100% alcohol to a 2% solution of celloidin; leave there 1 day.
2. Transfer to a 5% solution, 1 day.
3. Uncork the bottle until the celloidin thickens, but can still be poured.
4. Pour out into a dish and place objects in desired position.
5. When celloidin has thickened, harden by immersing in chloroform 3 hours and then cut into blocks and keep in 80% alcohol until ready for use, when you attach to a block and cut sections 10 to 20 microns thick.

II. To Stain and Mount Celloidin Sections.

1. Put loose sections in Haematoxylin stain 5 to 30 minutes.
2. In clear water, 5 minutes.
3. Decolorize in acid alcohol, 1 second or longer.
4. 70% alcohol, 1 minute.

4a. (If you wish to double stain put into Eosin 2 to 5 minutes and then in 70% alcohol, 1 minute.)

5. Dehydrate in 95% alcohol, 5 minutes.
6. Clear in carbol-xylol, 5 minutes.
7. Mount in Canada Balsam.

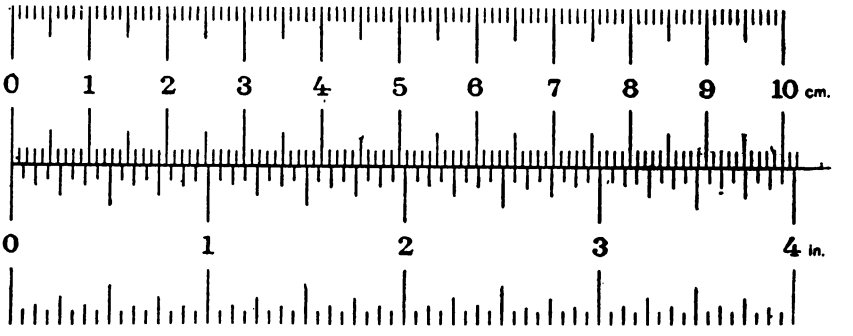
ACID DYES Color Cytoplasm	BASIC DYES Color Chromatin and Basophile Granules
Acid fuchsin	Fuchsin
Bismark brown	Haematein
Congo red	Gentian violet
Eosin	Methylene blue
Methyl blue	Methylene green
Orance G.	Methyl violet
Picric acid	Safranin

How to Make Diluted from Stronger Solutions.

If you are required to make a 75% solution of alcohol from one of 95% strength, pour into a graduate 75cc. of the latter and add water until the 95 cc. mark is reached.

General Rule: To obtain a given percentage of a substance in solution, subtract the percentage of the substance required from the percentage of the substance in solution to be diluted. The difference shows how much water should be added.

Example: Make a 3% solution of HCL from a 10% solution. 10—3=7. Adding 7 parts of water to 3 parts of the 10% solution gives us a 3% solution of HCL.



MEASURES

Length.—The microscopical unit of linear measure is the micron* or micromillimeter which is one thousandth of a millimeter (.001 mm). One thousand microns (1000 μ) equal the millimeter, another unit. One thousand millimeters (100 mm) equal the meter, a still larger unit.

Meter		Millimeters		Microns	Inches
1M	=	1000mm	=	1,000,000μ	= 39.37 in.
		1	=	1,000	= .03937
				1	= .000039
.0254	=	25.4	=	25,400.	= 1.

Capacity.—A cube 1 cm each way contains a milliliter.
1000 milliliters=1 liter or a cubic decimeter.
This volume of water at 4°C. weighs a kilogram.

Weight.—1 kilogram (kilo) = 1000 grams (grammes).
1 gram (g. or gm) = 1000 milligrams (mg.)

Remember that 1 cubic centimeter (cc or cm^3) of water weighs one gram and that 1 liter (L) which contains 1000 cc weighs a kilo.

*This may be further subdivided into millimicrons, 1000 $\mu\mu$ = 1 μ.

EQUIVALENT MEASURES

1 gram	=	15.4324 grains
1 grain	=	.0648 gram
1 ounce (avoirdupois)	=	28.3495 "
1 ounce (apothecary)	=	31.10348 "
1 fluid ounce	=	29.5737 cc
1 fluid drachm	=	3.6967 "
1 minim	=	.05916 "
1 cubic centimeter	=	16.9 minims

THE METRIC SYSTEM OF WEIGHTS AND MEASURES

The advantage of using one and the best system throughout the entire world is apparent. The advantages of the metric system are: The decimal relation between the units; the extremely simple relation of the units of length, area, volume and weight to one another; the uniform and self-defining names of units.

SYNOPSIS OF THE SYSTEM

Prefixes	Meaning		Units
milli = one thousandth	$\frac{1}{1000}$	.001	"meter" for length.
centi = one hundredth	$\frac{1}{100}$	.01	
deci = one tenth	$\frac{1}{10}$	.1	
Unit = one		1	"liter" for capacity
deka = ten	$\frac{10}{1}$	10	
hecto = one hundred	$\frac{100}{1}$	100	"gram" for weight
kilo = one thousand	$\frac{1000}{1}$	1000	

OBJECTIVES

Dry Series, Water-Immersion and Oil Immersion Lenses.

Objective		Fo (Focal Length) mm	Fo (Focal Length) inch	N. A. (Numerical aperture)	Micrometer Values measured with Eyepiece II
Dry Series	1	40	$1\frac{1}{2}$	.11	.062mm =62 μ
	2	24	1	.21	.030mm =30 μ
	3	16.2	$\frac{2}{3}$	.30	.017mm =17 μ
	4	10.	$\frac{2}{5}$	.47	.009mm = 9 μ
	5	5.4	$\frac{1}{5}$	.77	.0054mm= 5.4 μ
	6	4.0	$\frac{1}{6}$	.82	.0037mm= 3.7 μ
	7	3.2	$\frac{1}{8}$	.85	.0029mm= 2.9 μ
Water Immersion	10	2.1	$\frac{1}{12}$	1.20	.0018mm = 1.8 μ
Oil Immersion	$\frac{1}{12}$	1.8	$\frac{1}{12}$	1.30	.0017mm = 1.7 μ

EYEPIECES

Designation	0	I	II	III	IV	V
Focal Length	62.5	50.	41.65	31.25	25	20.85mm
Magnification	4	5	6	8	10	12 diameters

REFRACTIVE INDEX

Air	1.	Canada Balsam	1.526
Water	1.334	Crown Glass	1.535
Cedar Oil	1.510	Flint Glass	1.625

Microscope Manufacturers

Of the U. S.
- Bausch & Lomb Co., Rochester, N. Y.
- Spencer Lens Co., Buffalo, N. Y.

English
- Baker, Chas., London, England.
- Beck, R. & J., London, England.
- Powell & Lealand, London, England.
- J. Swift & Son, London, England.
- W. Watson & Sons, London, England.

German
- Carl Reichert, Vienna, Austria.
- Ernst Leitz, Wetzlar, Germany.
- Voigtlaender, Brunswick, Germany.
- Paul Waechter, Friedenau, Germany.
- Carl Zeiss, Jena, Germany.

Fig. 1.

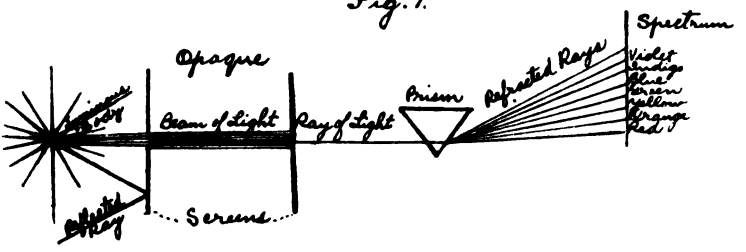


Fig. 2. To show the relation between prisms and lenses.

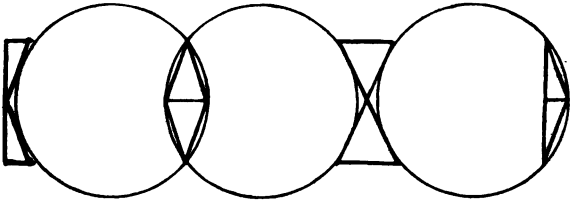
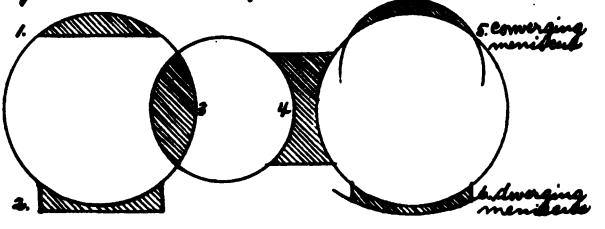


Fig. 3. Lenses are Segments of Spheres.



1. Planoconvex. 2. Planoconcave. 3. Biconvex.
4. Biconcave. 5. Concavoconvex. 6. Convexoconcave.

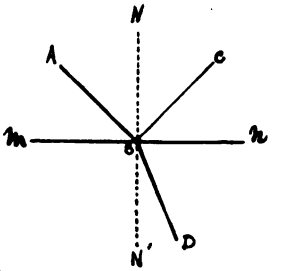


Fig. 4. AB, an incident ray. BC, the reflected ray. BD, the refracted ray. DBN' is the angle of refraction.

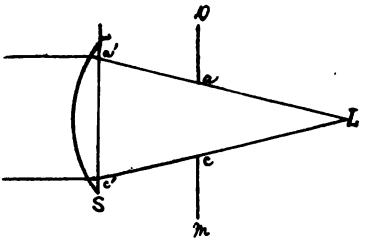


Fig. 5. L is source of light; ac, the diameter of diaphragm; a'c', the working aperture of the lens

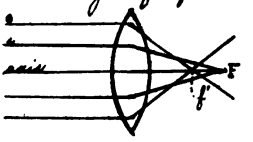


Fig. 6. Spherical Aberration. An outer ray comes to a focus sooner than an inner ray.

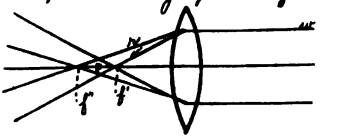


Fig. 7. Chromatic Aberration. The red waves of white light come to a focus beyond the focus for violet waves

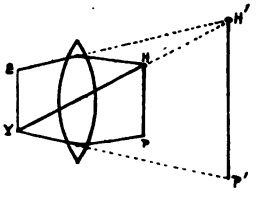


Fig. 8. Principle of Magnifying Glass or Eyepiece of Microscope. H'P' is an erect virtual image.

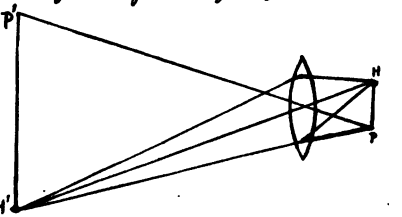


Fig. 9. Principle of Objective of Microscope. P'H' is an inverted and real image. H and H' are conjugate foci.

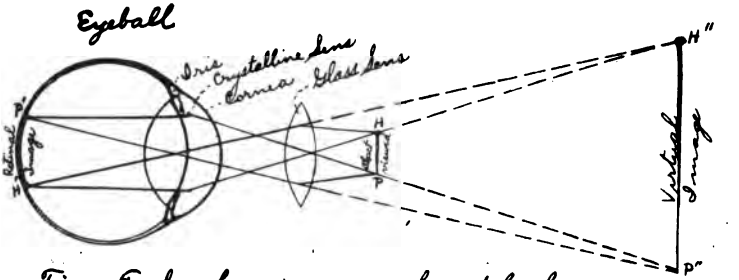


Fig. 10. To show how images are formed by lenses.

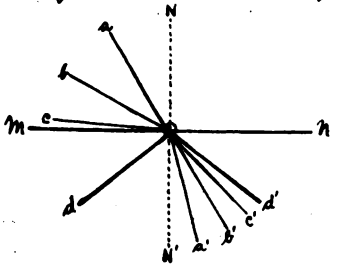


Fig. 11. The ray a o is refracted to a', b o to b', c o to c'. If the incident ray came from c', it would be refracted to c. For any incident angle larger than c' o n' or the critical angle, the incident ray would not be refracted but we would get total reflection in the denser medium as d' o d.

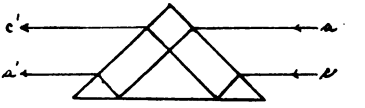


Fig. 12. The right angled or inverting prism.

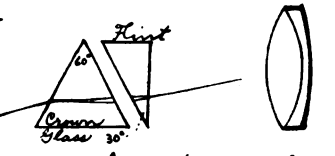


Fig. 13. Achromatic Prism & Lens.

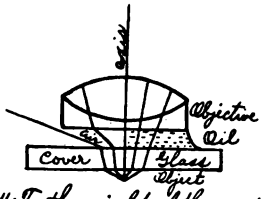
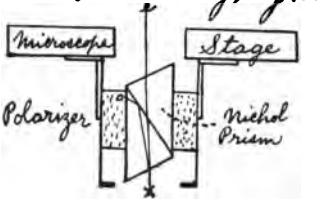


Fig. 14: To the right of the axis is shown the advantage of the oil immersion objective over the dry.

Fig. 15. The light coming from X is polarized, being divided by the Iceland spar into the ordinary ray XO and the extraordinary ray Xe.



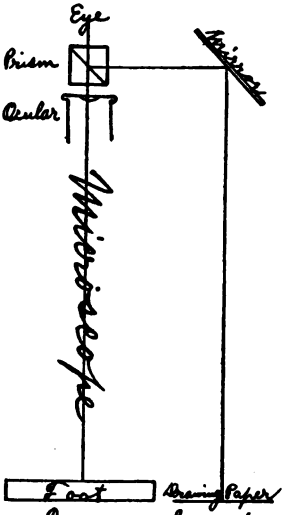


Fig 16. Camera Lucida for making drawings.

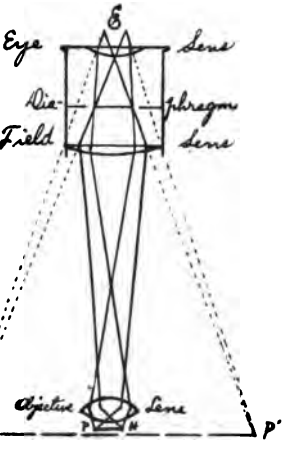


Fig. 17. To show how the compound microscope magnifies things.

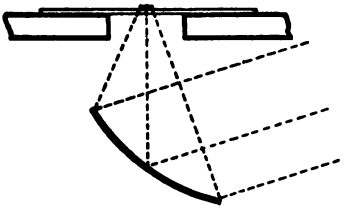


Fig. 18.—Illuminating object with concave mirror. (This and Figs. 19 and 20 are from Bausch, Use and Care of the Microscope.)

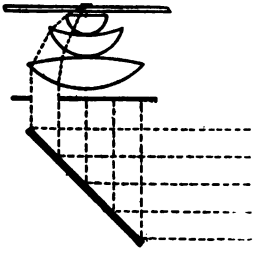


Fig. 19.—Illuminating object by oblique light with condenser.

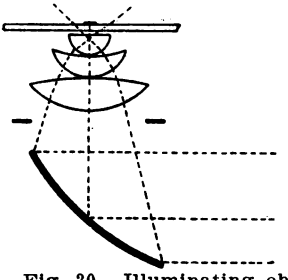


Fig. 20.—Illuminating object with condenser and concave mirror. The wrong way.

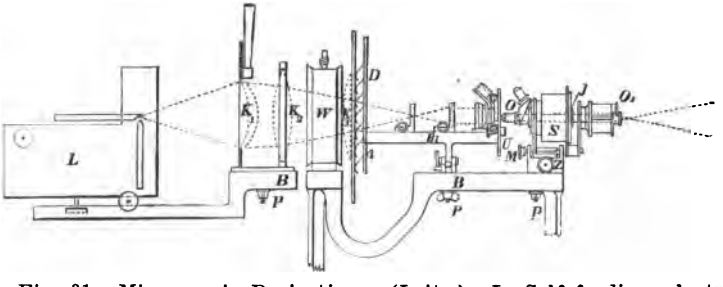


Fig. 21.—Microscopic Projection. (Leitz.) L, Self-feeding electric arc lamp. W, Cooling chamber containing water. D, Lantern slide carrier. O, Objective near the object to be projected. O', The interchangeable oculars. Z, Coarse adjustment. M, Fine adjustment. The small optical bench, B, has three stands, which may be moved along the optic axis by a rack and pinion gear. The first stand, reckoned from lens K_3, is fitted with an iris-diaphragm, the second with a lens, and the third with a centering sleeve for two condensers. The judicious displacement of these stands furnishes a means of obtaining the proper illumination.

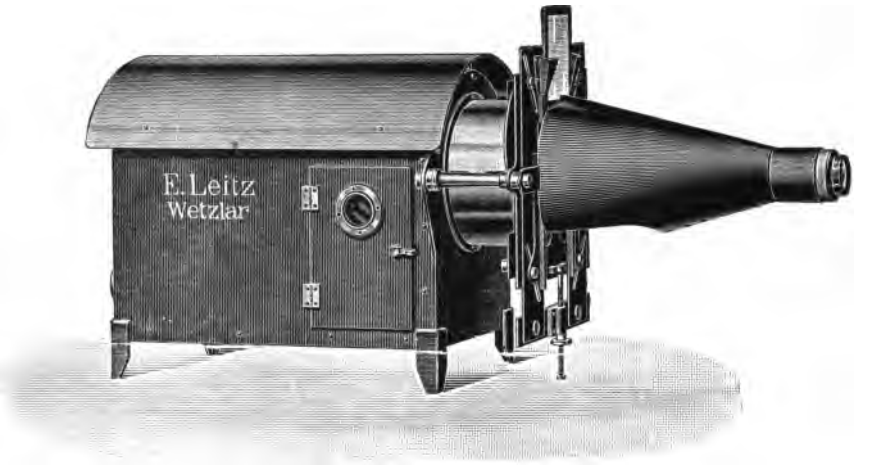


Fig. 22.—A Simple Projection Apparatus.

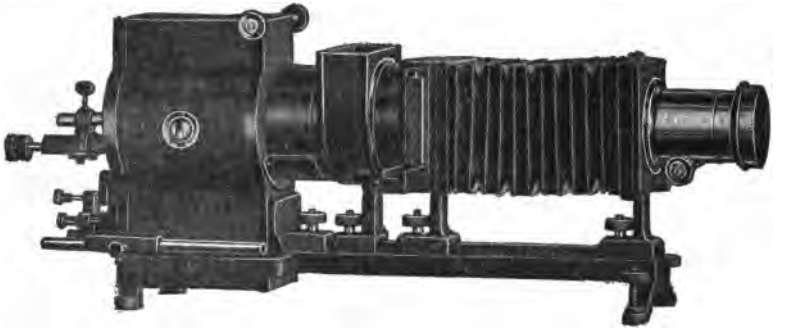


Fig. 23.—Balopticon for Projection and Photo-micrographic work (Bausch & Lomb.)

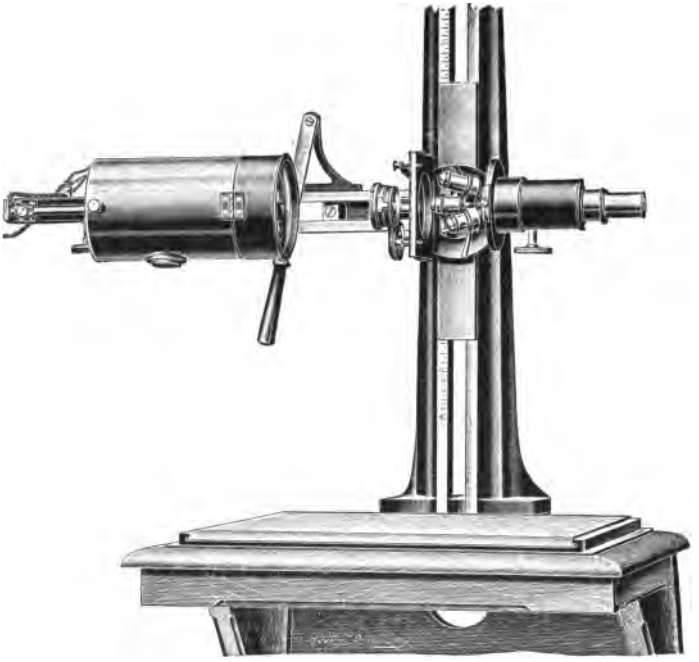


Fig. 24.—Edinger's Drawing and Projection Apparatus. (Leitz.)

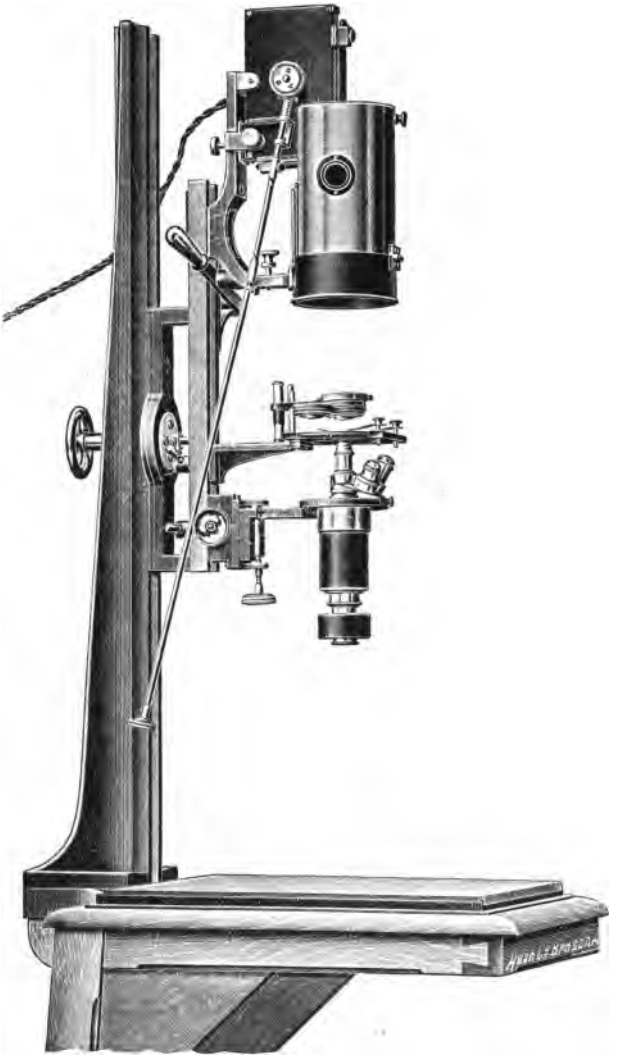


Fig. 25.—Edinger's Drawing and Projection Apparatus in vertical position. (Leitz.)

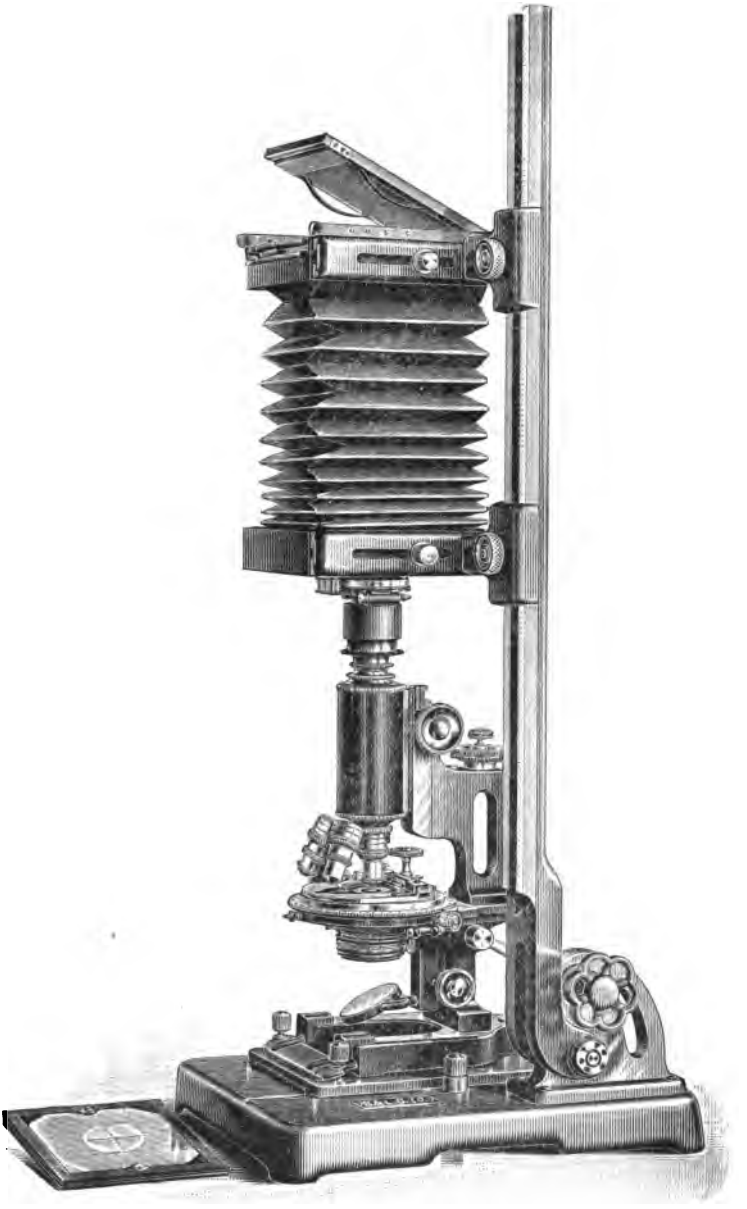


Fig. 26.—Photo-micrographic Camera. (Bausch & Lomb Optical Co.)

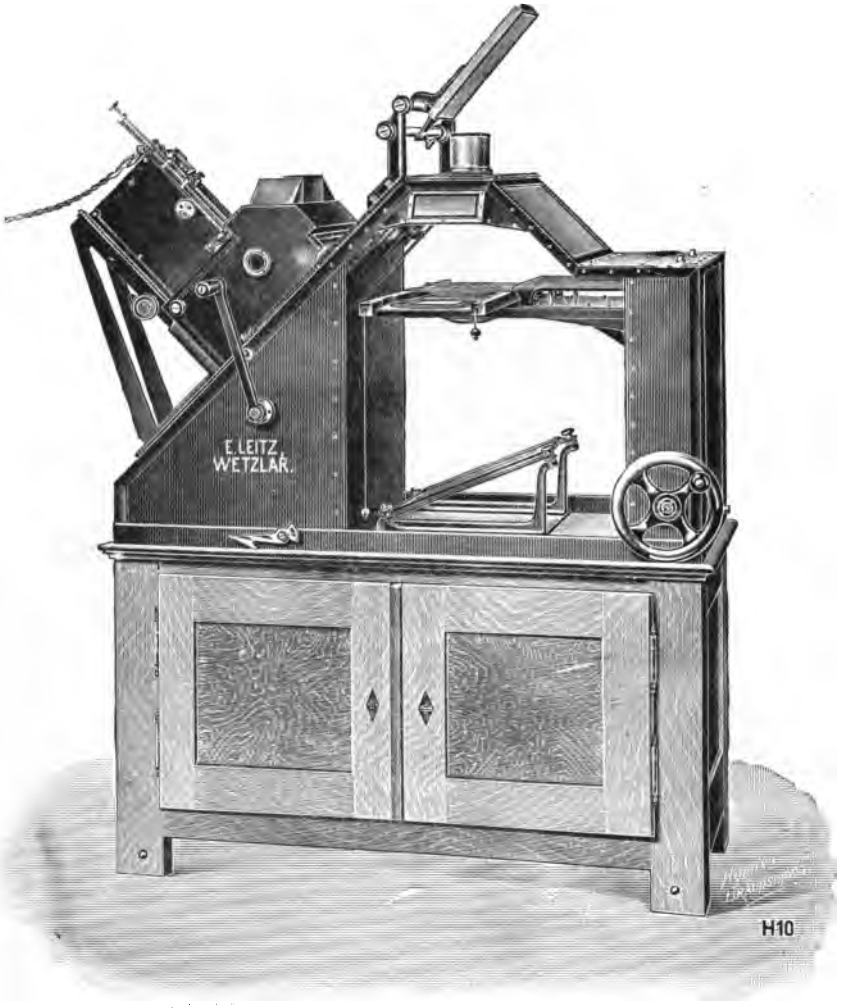


Fig. 27.—Leitz Apparatus for Episcopic Projection.

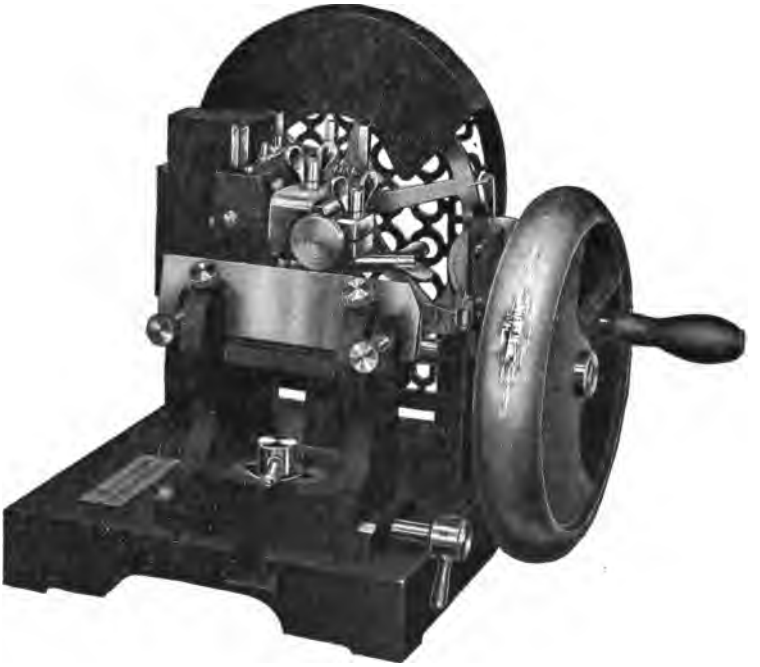


Fig. 28.—Bausch & Lomb's New Model Automatic Microtome.

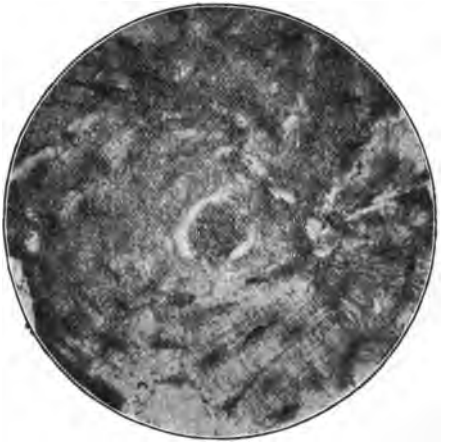


Fig. 29.—Photo-micrograph of a Cross-Section of Bone. x225. (Bausch & Lomb.)

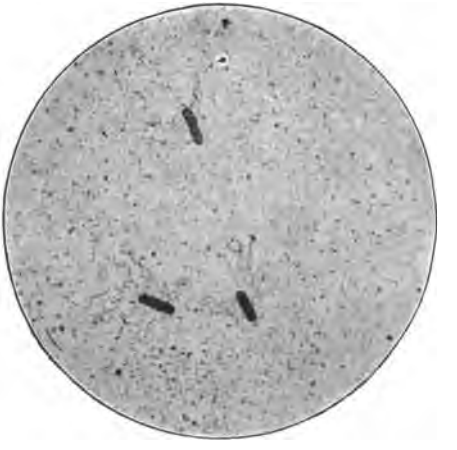


Fig. 30.—Photo-micrograph of Bacillus Typhosus with Flagella x1500. (Bausch & Lomb.)

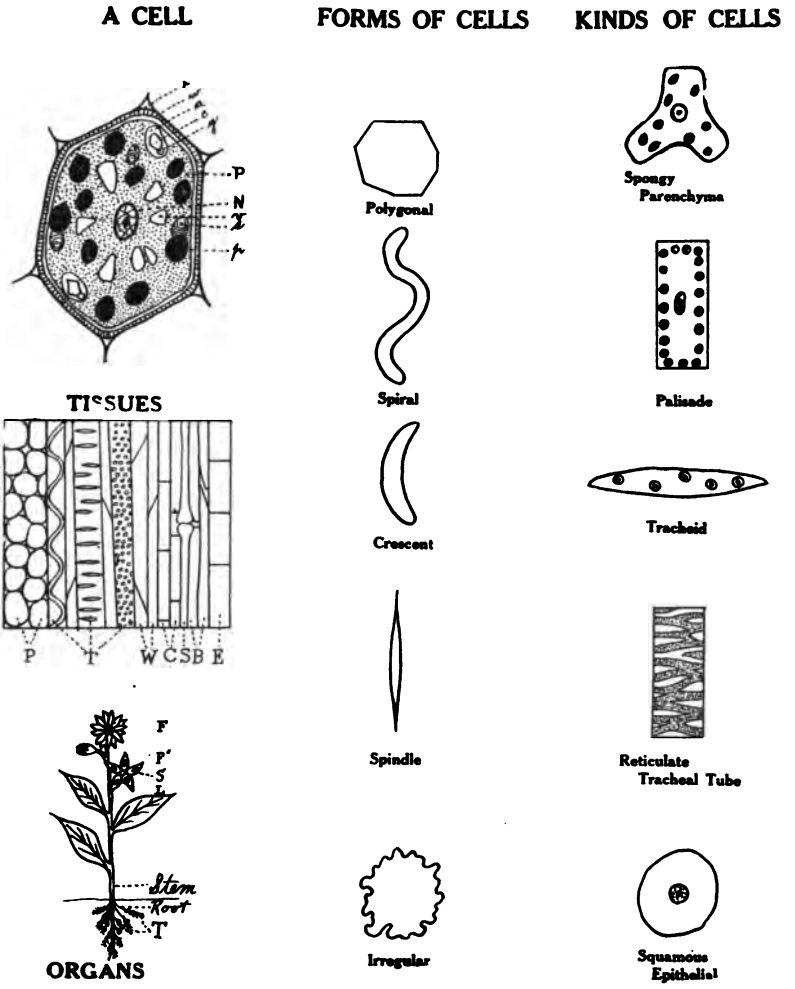


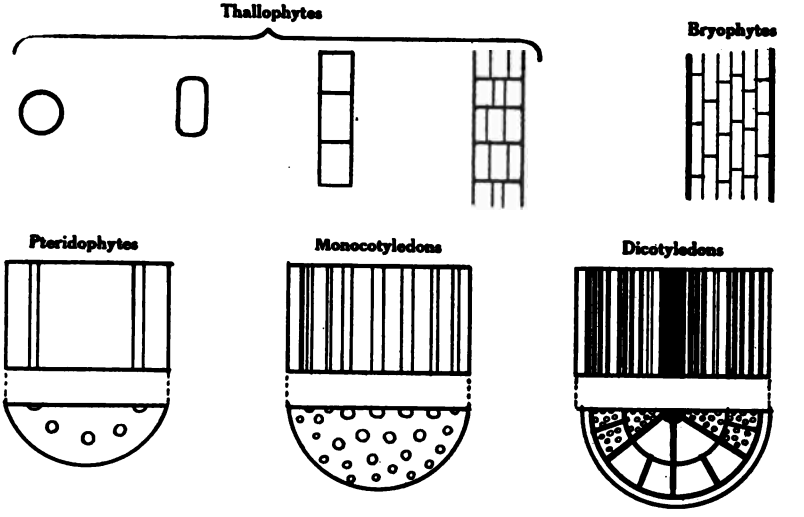
Fig. 31.—Under **CELL,** i, intercellular space. w, cell-wall. a, aleurone grain, containing c, a crystalloid and g, a globoid. P, protoplasm. N, the nucleus. v, a vacuole. s, starch grain, produced by p, a plastid. Under **TISSUES,** P, pith. T, trachial tubes. W, wood fibers. C, companion cells. s, sieve tube. B, bast. E, epidermis.

Under **ORGANS,** F, flower. F', fruit. S, seed. L, leaf. T, trichomes or root hair.

Fig. 32.--DIFFERENT STAGES OF INDIRECT NUCLEAR AND CELL DIVISION.

A shows the resting nucleus. Its chromatin network has formed into thick V-shaped segments in B. In C these chromosomes have split longitudinally and are being drawn to the polar bodies by the threads of the spindle. D. The daughter chromosomes are at the poles, where they form (E) a band which then forms the nuclear reticulum of the daughter cell.

Fig. 33.— EVOLUTION OF THE STEM.



The lower row shows one-half of a cross section of the stem, a part of the longitudinal section of which is seen immediately above it. The fibro-vascular bundles are indicated and under **dicotyledons** also the pith (in the center) and the medullary rays radiating from it.

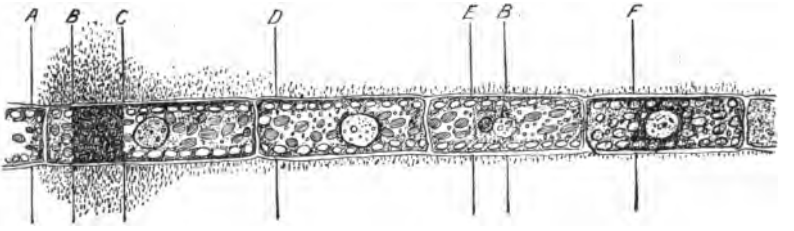


Fig. 34.—A Filament of Oedogonium as seen when mounted on a drop of water containing oxygen-loving bacteria and illuminated by means of light which has passed through a spectroscope placed beneath the stage of the microscope. The bacteria collect along the filament in greatest numbers between the lines B and C, which corresponds to the region of greatest absorption by the chlorophyll of the filament. (Sayre after Pfeffer.)

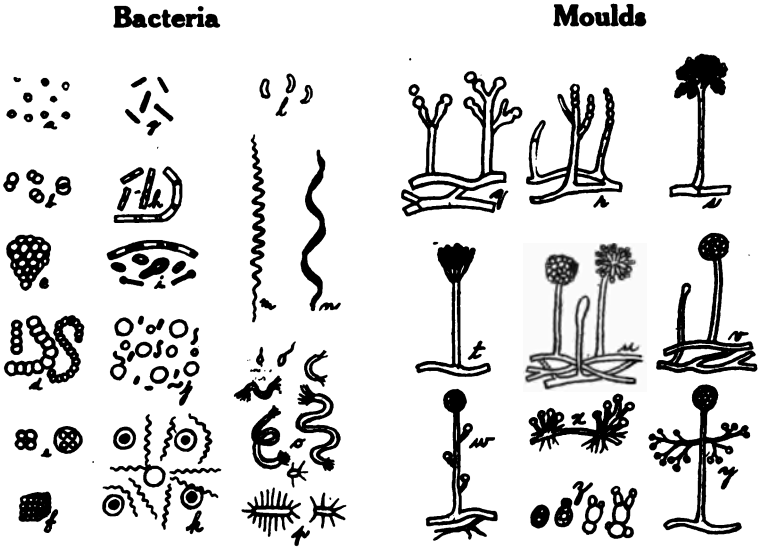


Fig. 35.—Various Forms of Fungi. a, the Micrococcus. b, Diplococcus. c, Staphylococcus. d, Streptococcus. e, Tetrad. f, Sarcina. g, Bacillus. h, Bacilli in chain formation. i, Bacilli containing spores. j. Bacilli and Spirilla among the globules of fat in market milk. k. Spirillum or Spirochaeta Obermeieri (of Relapsing Fever) among red blood corpuscles. l, Spirillum Cholerae Asiaticae (Comma Bacillus of Cholera). m, Spirochaeta Pallida. n, Spirochaeta refringens with undulating membrane. o, p, Bacteria with flagella. q, Penicillium brevicaule. r, Oidium lactis. s, Botrytis cinerea. t, Penicillium crustaceum. u, Aspergillus herberiorum. v, Mucor mucedo. w, Mucor racemosus. x. Mucor stolonifer. y, Thamnidium elegans. z, Yeast.

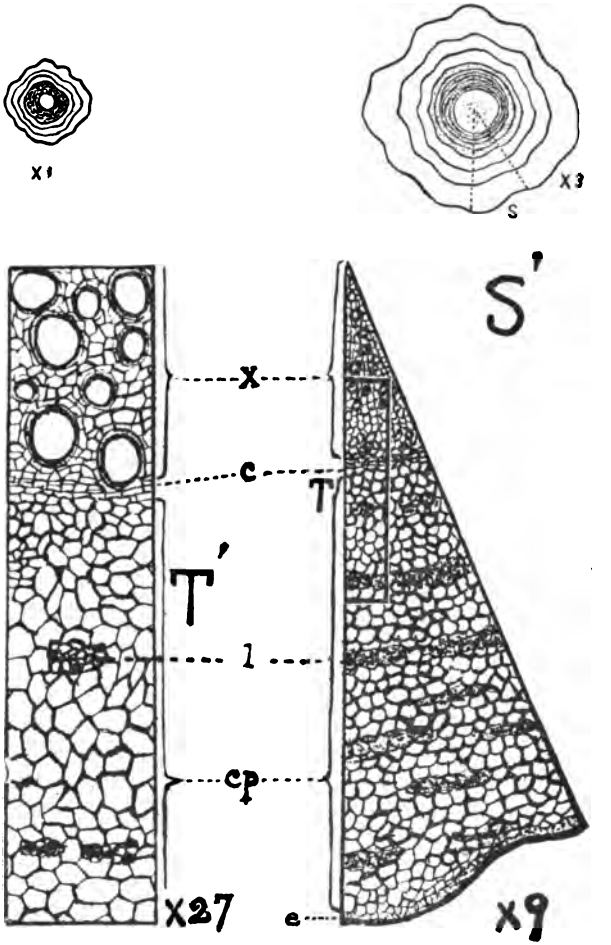


Fig. 36.—Taraxacum. Cross-section of Dandelion Root. The sector S is shown enlarged three times at S'. A part of the latter, T, is shown enlarged three times at T'. X, Xylem with wood parenchyma surrounding the large tracheal tubes. c, Cambium. l, Laticiferous vessels and sieve tubes in cp, the cortical parenchyma. e, Epidermis or bark.

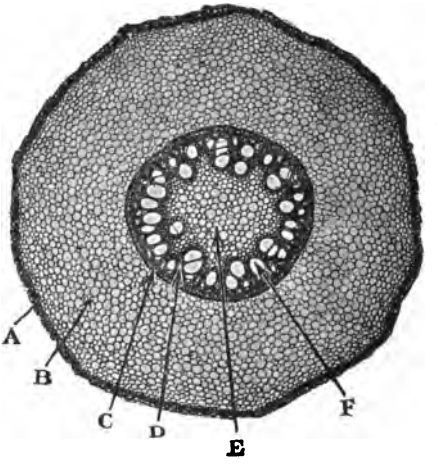


Fig. 37.—Sarsaparilla, Honduras. Cross-section of root. (18 diam.) A, Epidermis. B, Parenchyma of cortex. C, Endodermis. D, Wood parenchyma and fibers. E, Medulla. F, Water tube.

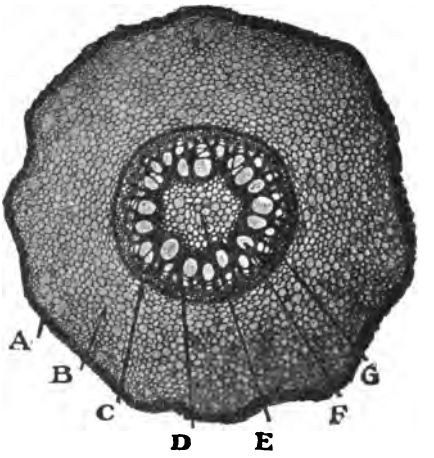


Fig. 38.—Sarsaparilla, Jamaica. Cross-section of root. (21 d'am.) A, Epidermis. B, Parenchyma of cortex. C, Endodermis. D, Wood parenchyma and fibers. E, Medulla. F, Water tube. G, Phloem. (Photomicrographs from Sayre's Organic Materia Medica and Pharmacognosy.)

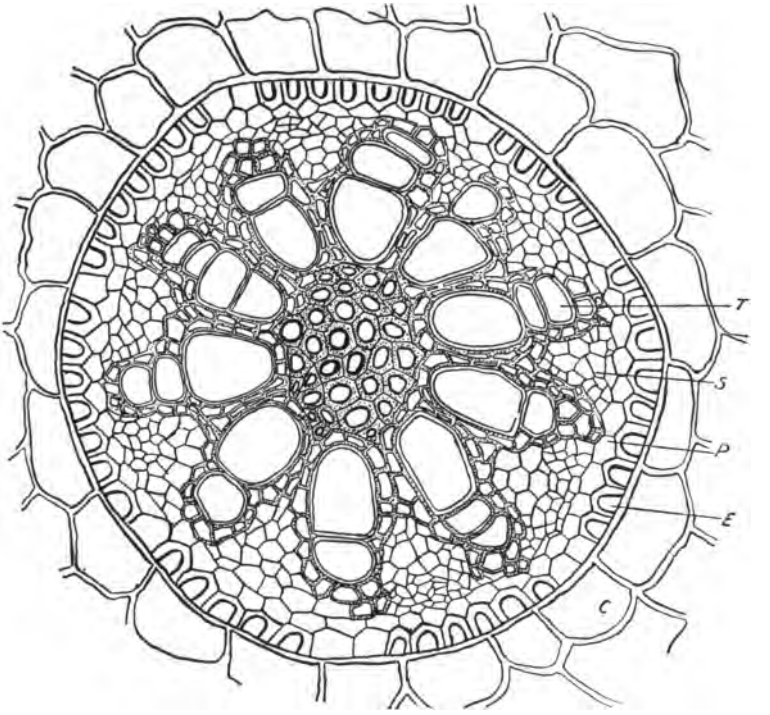


Fig. 39.—Cross-section through a portion of Root of Veratrum album. C, Cortical parenchyma. E, Endodermis. P, Pericycle. S, Phloem. T, Xylem. At the center, within the circle of vascular bundles, occur thick-walled sclerenchymatous cells. (Sayre after Tschirch.)

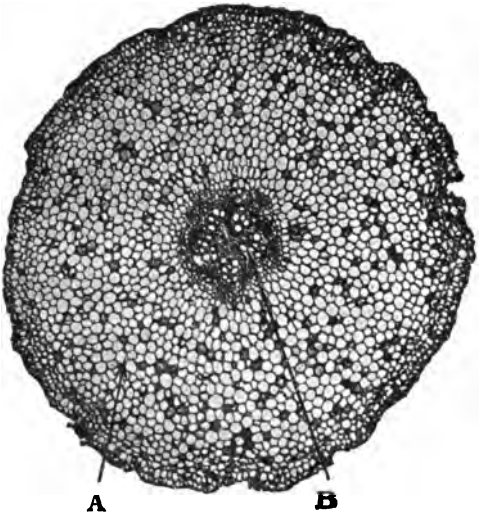


Fig. 40.—Podophyllum. Cross-section of rootlet. (25 diam.) A, Cortex. B. Xylem. (Sayre.)

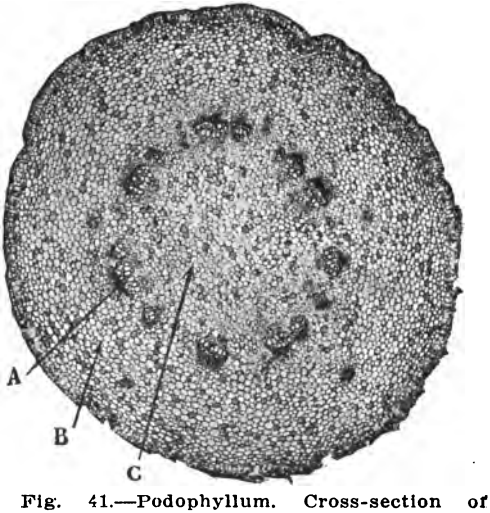


Fig. 41.—Podophyllum. Cross-section of rhizome. (15 diam.) A, Vascular bundle. B, Parenchyma of cortex. C, Medulla. (Sayre.)

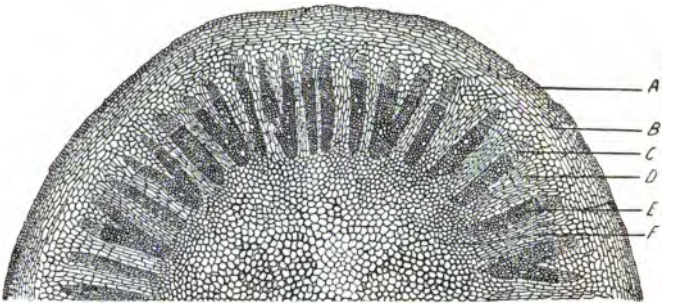


Fig. 42.—Caulophyllum. Cross-section of rhizome. A, Epidermis. B, Parenchymatous tissue. C, Phloem portion of bundle. D, F, Medullary rays. E, Xylem portion of bundle. (Sayre.)

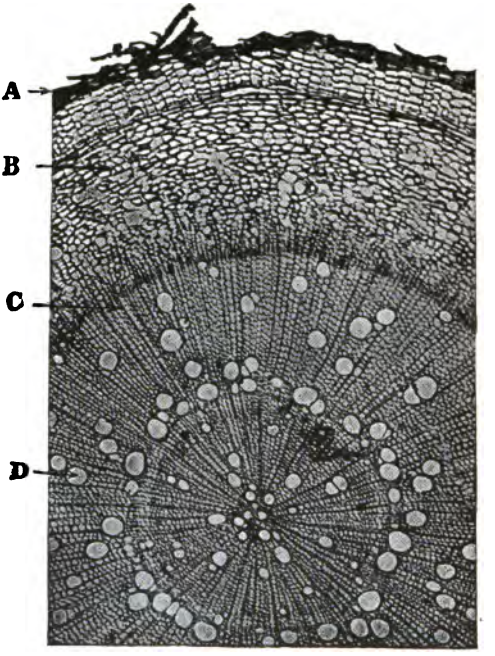


Fig. 43.—Apocynum cannabinum. Cross-section of rhizome. (28 diam.) A, Cork. B, Parenchyma of cortex. C, Medullary ray. D, Water tube. (Sayre.)

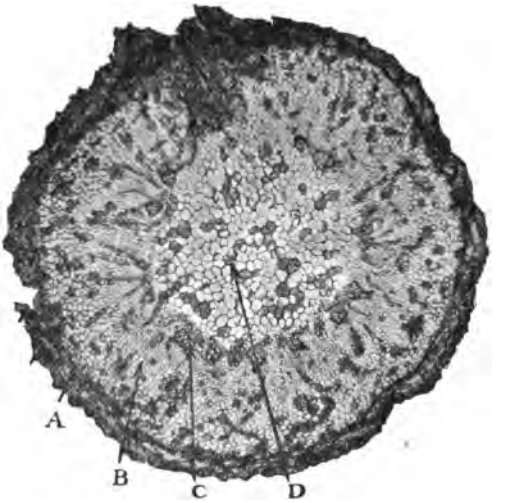


Fig. 44.—Aconite Tuber. Cross-section. (14 diam.) A, Cork. B, Parenchyma of cortex. C, Vascular bundle. D, Medulla. (Sayre.)

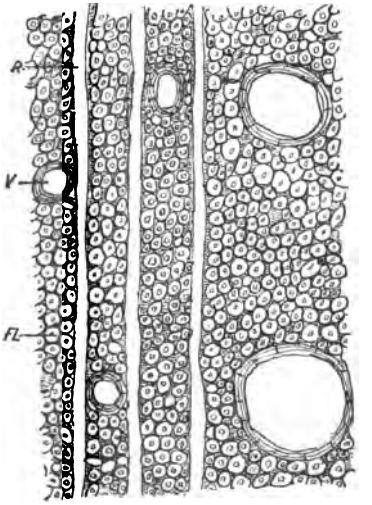


Fig. 45.—Guaiacum. Cross-section of wood. R, Medullary rays, composed of one, two and three ranges of cells. V, Closed vessels. FL, Ligneous fibers, very much developed and forming concentric zones. (Sayre.)

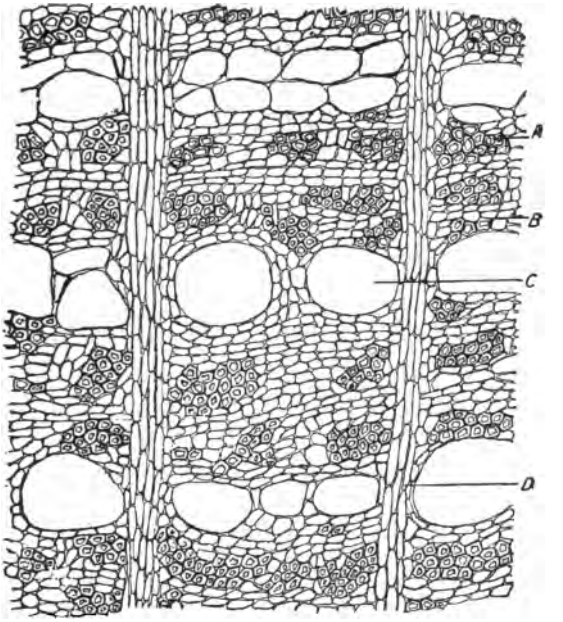


Fig. 46.—Ulmus. Cross-section of bark. A, Bast fibers. B, Parenchymatous tissue. C, Mucilage ducts. D, Medullary rays. (Sayre.)

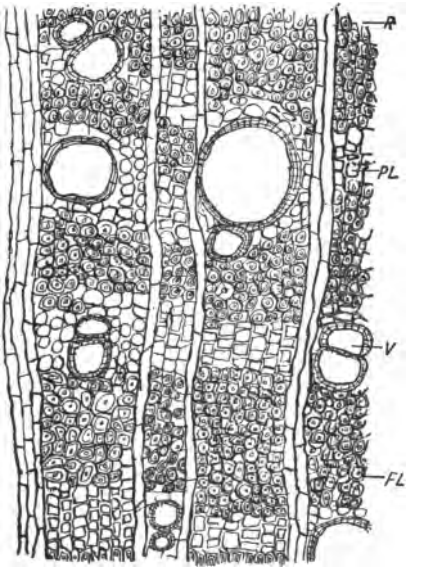


Fig. 47.—Haematoxylon. Cross-section of wood. R, Medullary ray, consisting of two vertical rows of cells, to which the black line from R should be extended. V, Pitted vessels. FL, Ligneous fibers. PL, Wood parenchyma. (Sayre.)

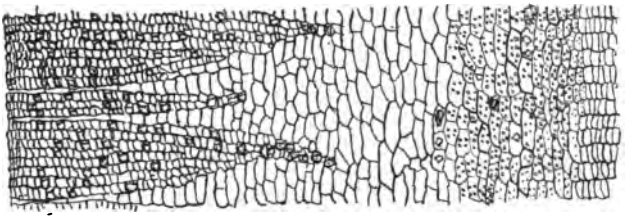


Fig. 48.—Punica granatum. Cross-section of the bark of the root. (Sayre.)

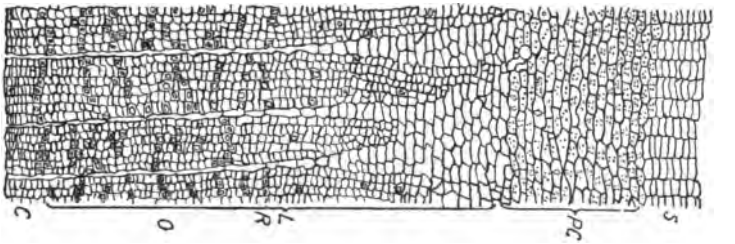


Fig. 49.—Punica granatum. Cross-section of bark of stem. S, Suberous layer. PC, Cortical parenchyma. L, Liber. R, Dotted line extends to narrow medullary ray. O, Stands opposite a tangential row of calcium oxalate crystals, which are numerous throughout the phloem. C, Cambium. (Sayre.)

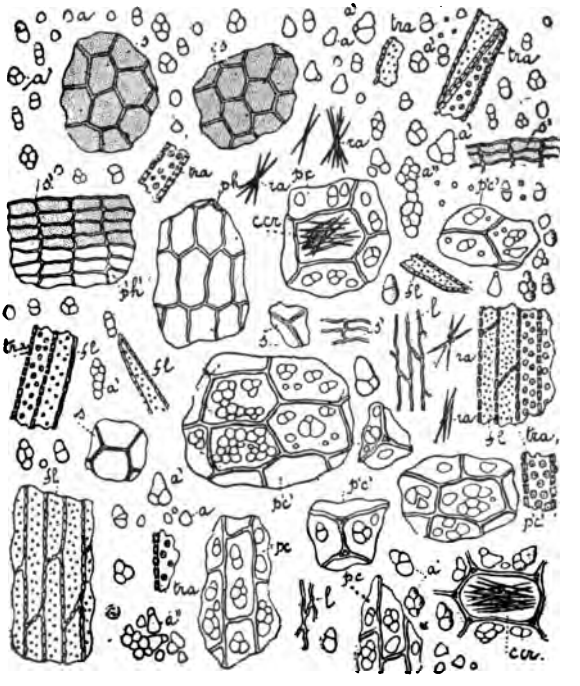


Fig. 50.—Powdered Undulated Ipecacuanha. (x210.) a, Starch grains. cr, Acicular crystals. fl, Pitted wood fibers. l, Bast. pc, Cortical parenchyma. ph, Phelloderm. s, s', Cork in surface view and section. v, Pitted vessels. (Sayre from Greenish and Collin.)

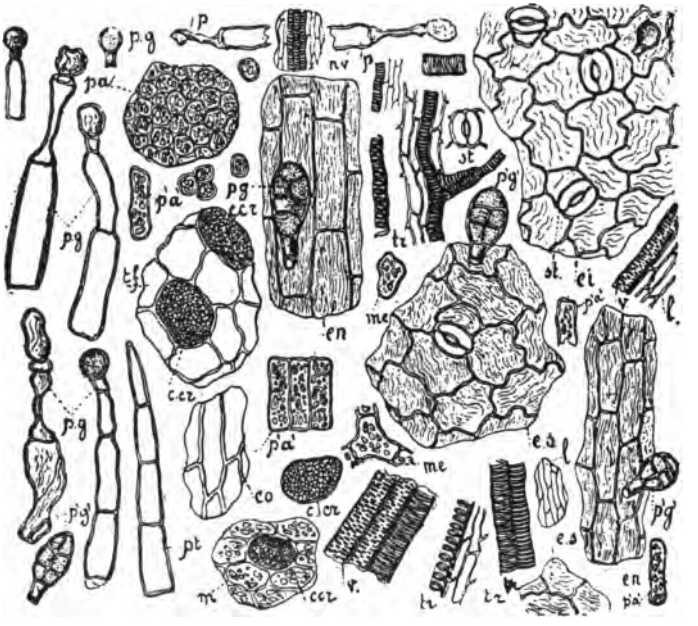


Fig. 51.—Powdered Beelladonna Leaevs. (x210.) c, cr, Cells with sandy crystals. co, Collenchymatous cells from cortical tissues of midrib. ei, Epidermis of under surface. en, Epidermis over the veins, with striated cuticle. es, Epidermis of the upper surface, with striated cuticle and occasional stomata. l, Bast. me, Branching cells of spongy parenchyma. nv, Fragment of small vein. pa, Palisade cells, surface view. pia1 Palisade cells in longitudinal section. pg, Glandular hair, long and short, with unicellular and pluricellular glands. st, Stomata, surrounded by three or four cells, one of which is smaller than the others. tf, Cortical tissues of the midrib. tr, v, Tracheids and vessels. (Sayre after Greenish and Collin.)

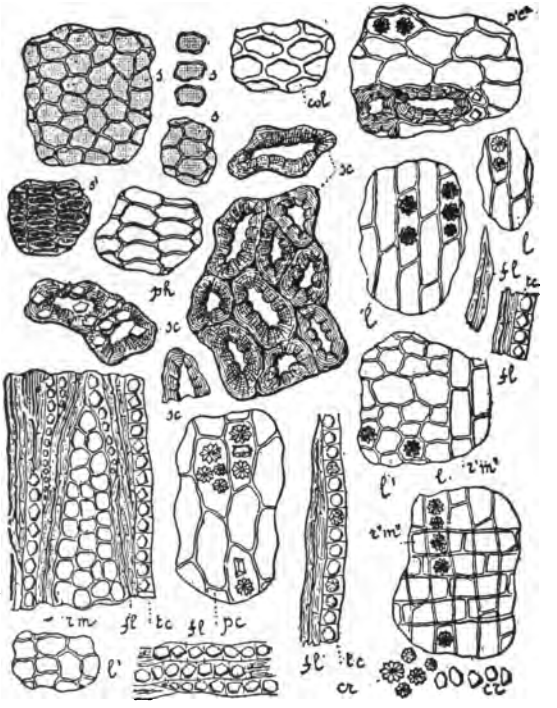


Fig. 52.—Powdered Cascara Sagrada Bark (Rhamnus Purshiana). (x210.) col, Collenchyma of the cortex. cr, Prismatic and rosette crystals. fl, Bast fibers. l, l′, Bast in longitudinal and transverse section. pc, p′c′, Cortical parenchyma in longitudinal and transverse section. ph, Phelloderm. rm, Medullary rays, tangential section. r′m′, The same, transverse section. r″m″, The same, radical section. s, s′, Cork, in surface view and section. sc. Sclerenchymatous cells. tc, Rows of crystal cells. (Sayre from Greenish and Collin.)

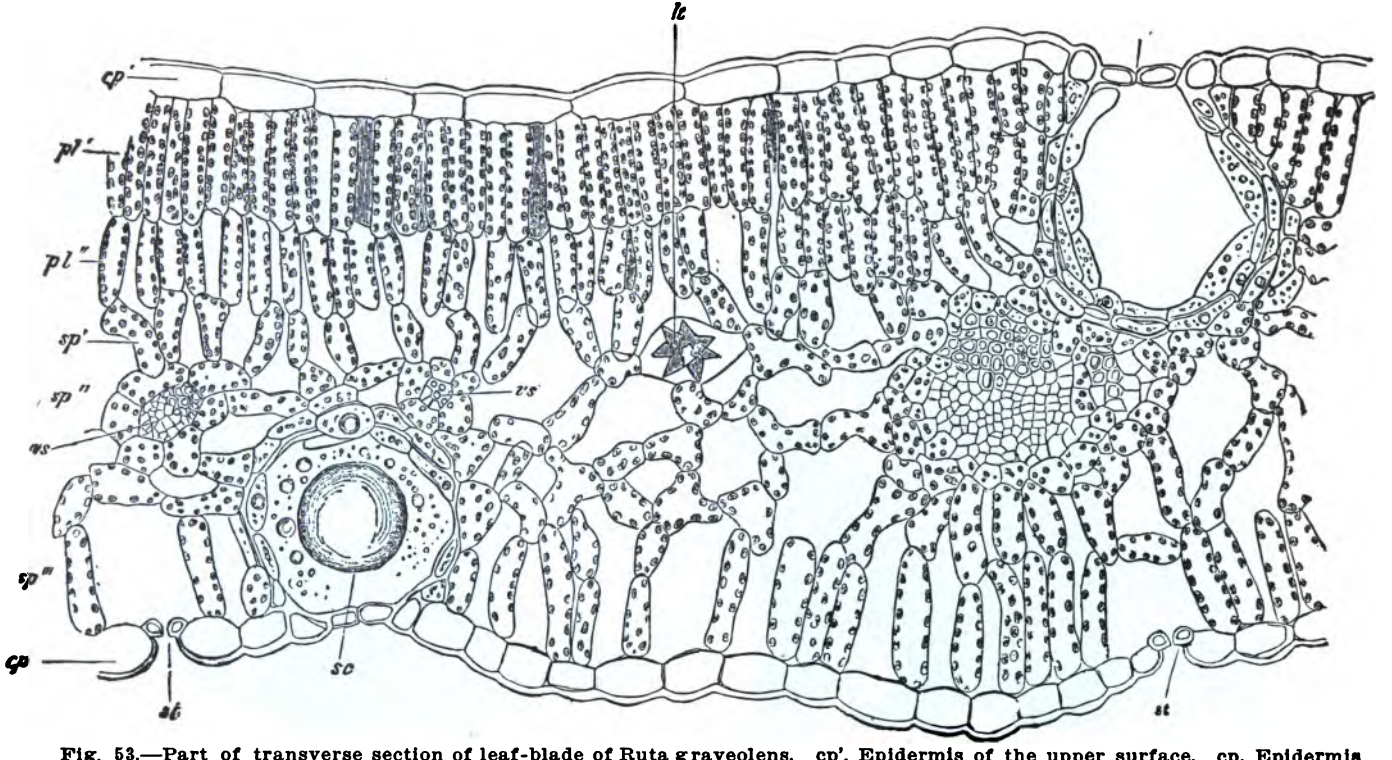


Fig. 53.—Part of transverse section of leaf-blade of Ruta graveolens. cp', Epidermis of the upper surface. cp, Epidermis of the lower surface. st, st, Stomata. pl,' pl'', Palisade cells. sp', sp'', sp''', Spongy tissue. k, Crystal sac. vs, vs, Small vascular bundles. sc, Lysigenous oil glands, the upper one empty. (Sayre after Strassburger.)

Microphotographs in Which the Student is to Identify and Label the Parts

Fig. 54.—Starch Grains under Polarized Light.

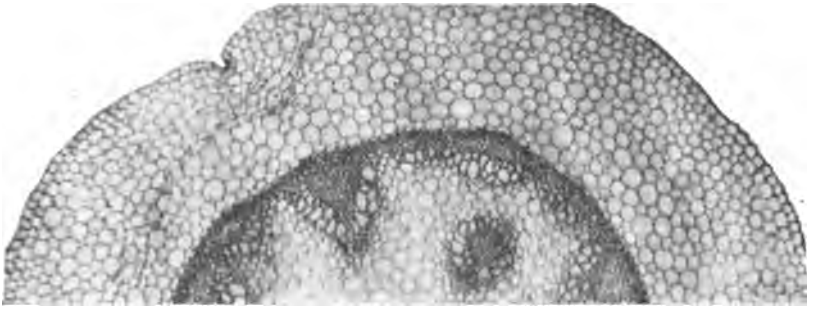


Fig. 55.—Convallaria Majalis. Transverse Section of Rhizome.

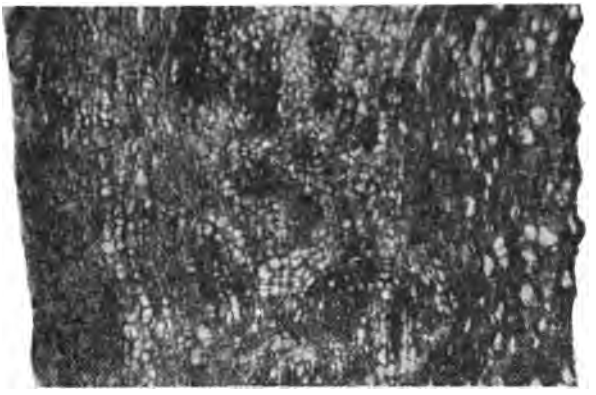


Fig. 56.—Cinnamomum Cassia. Transverse Section of Bark.

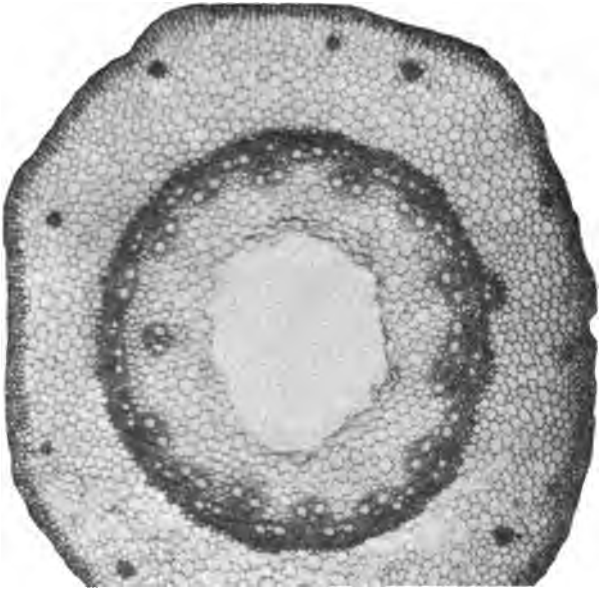


Fig. 57.—Agropyron Repens. Transverse Section of Rhizome.

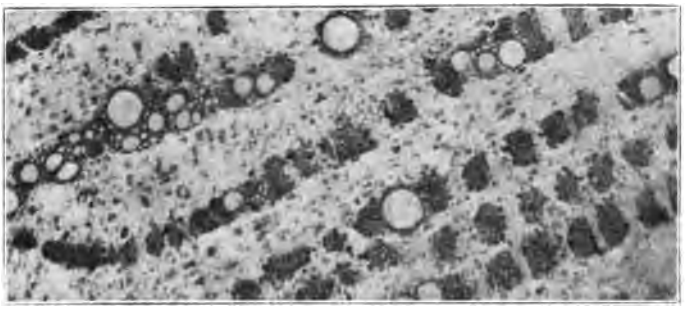


Fig. 58.—Glycyrrhiza Glandulifera. Transverse Section of Root.

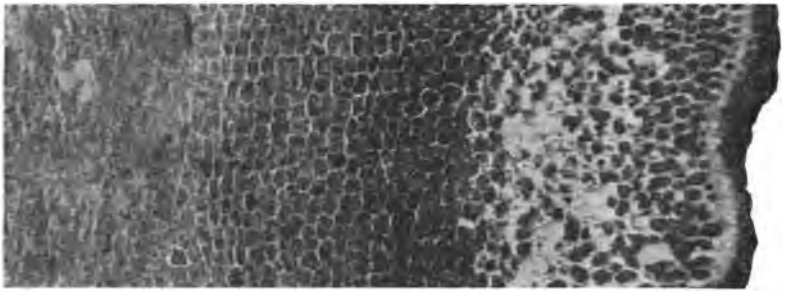


Fig. 59.—Cephaelis Acuminata. Longitudinal Section of Root of Carthagean Ipecac.

Fig 60.—Simple Dissecting Microscope. (Leitz.)

Fig. 61.--Erect-vision Dissecting Microscope.

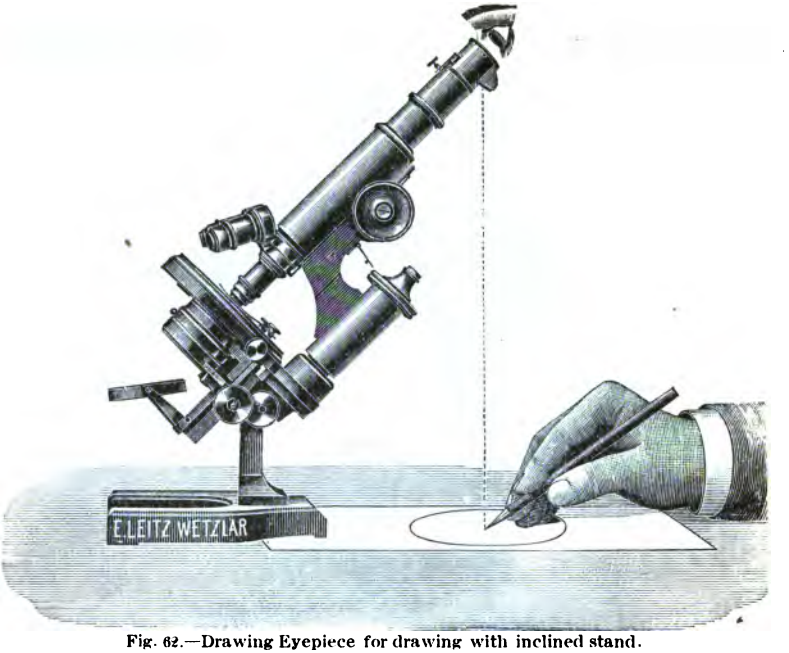


Fig. 62.—Drawing Eyepiece for drawing with inclined stand.

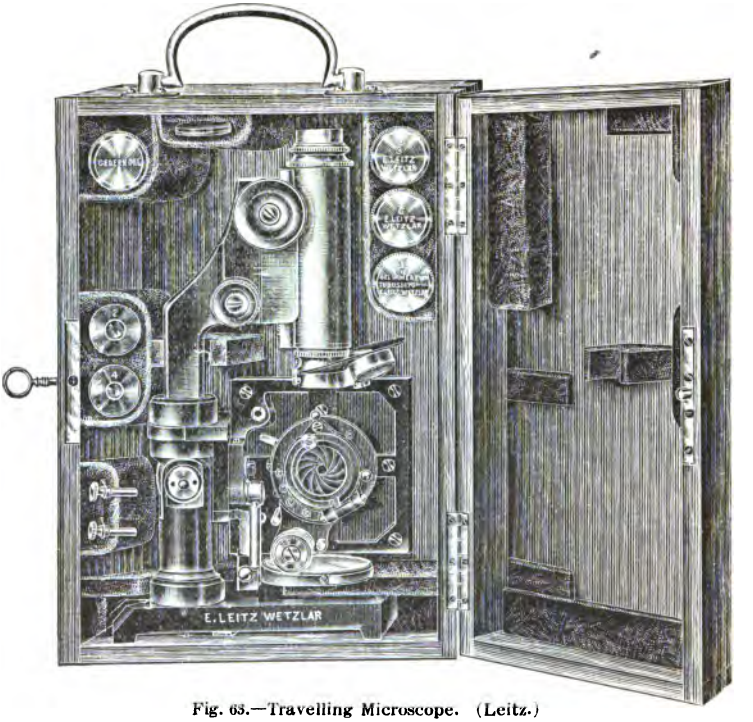


Fig. 63.—Travelling Microscope. (Leitz.)

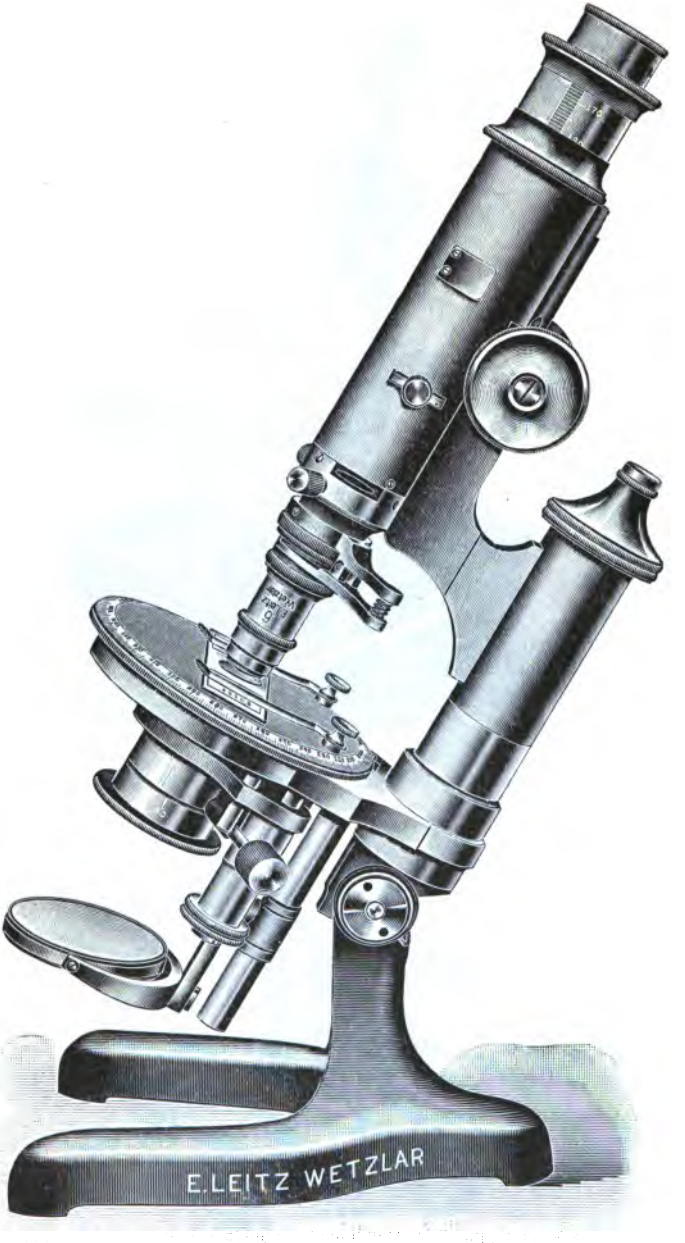


Fig. 64.—Minerological Microscope.

Fig. 65.—Meat Inspector's Travelling Microscope.

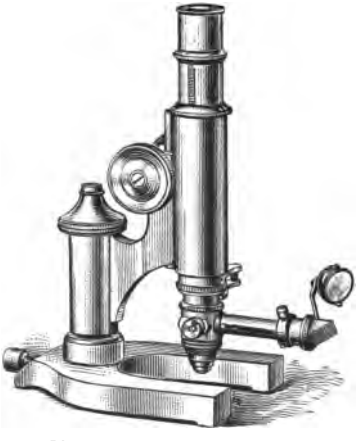


Fig. 66.—The Metallurgical Microscope. (Leitz)

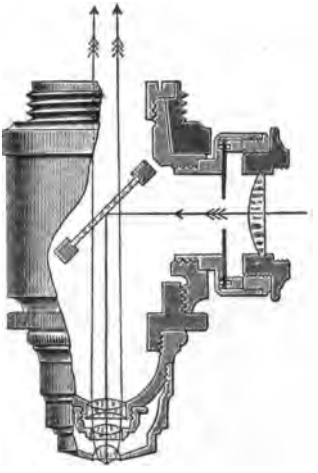


Fig. 67.—The Opaque Illuminator.

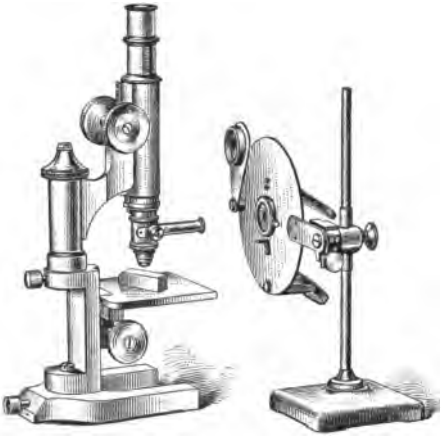


Fig. 68.—Microscope with New Opaque Illuminator. (Leitz.)

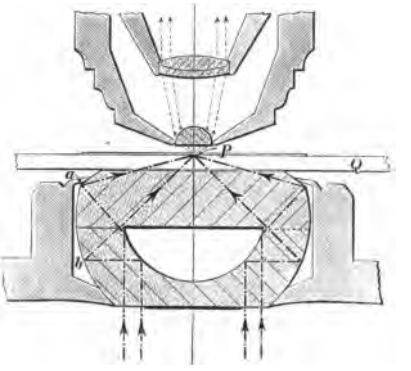


Fig. 69. – Darkground Illumination. (Leitz)

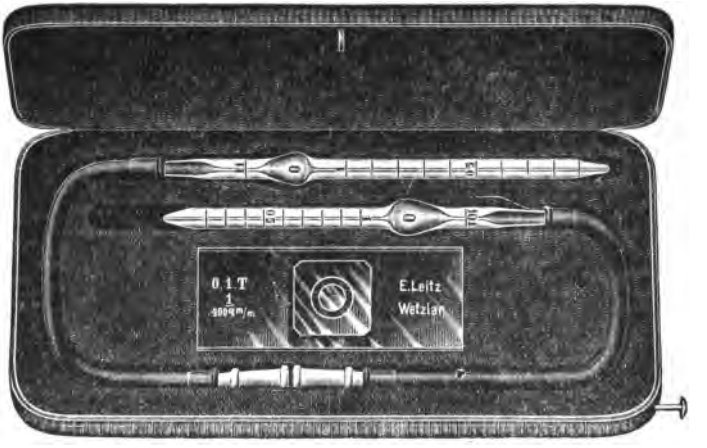


Fig 70.—Thoma's Haemacytometer consists of an object glass with accurately ruled cell, an optically plane cover-glass and two calibrated mixing pipettes.

1. For red blood-corpuscles, diluting to 1-100 and 1-200,
2. For white blood-corpuscles, diluting to 1-10 and 1-20.

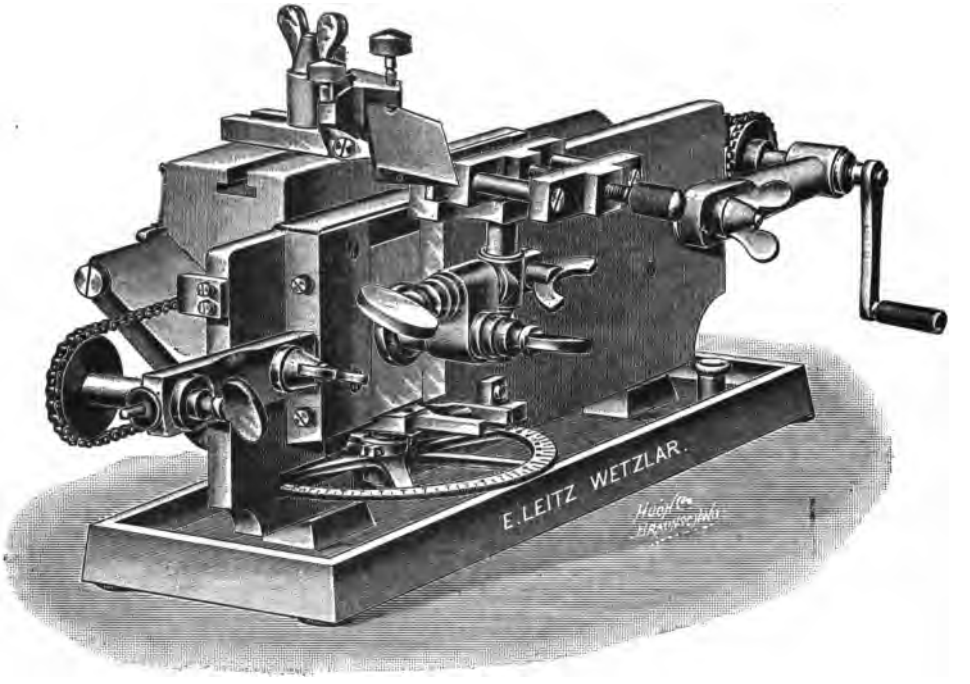


Fig. 71.— Large Sliding Microtome.

Notes and Drawings

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